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SCIENCE ON THE MARCH
UNIT THREE

THE WEATHER AND THE EARTH

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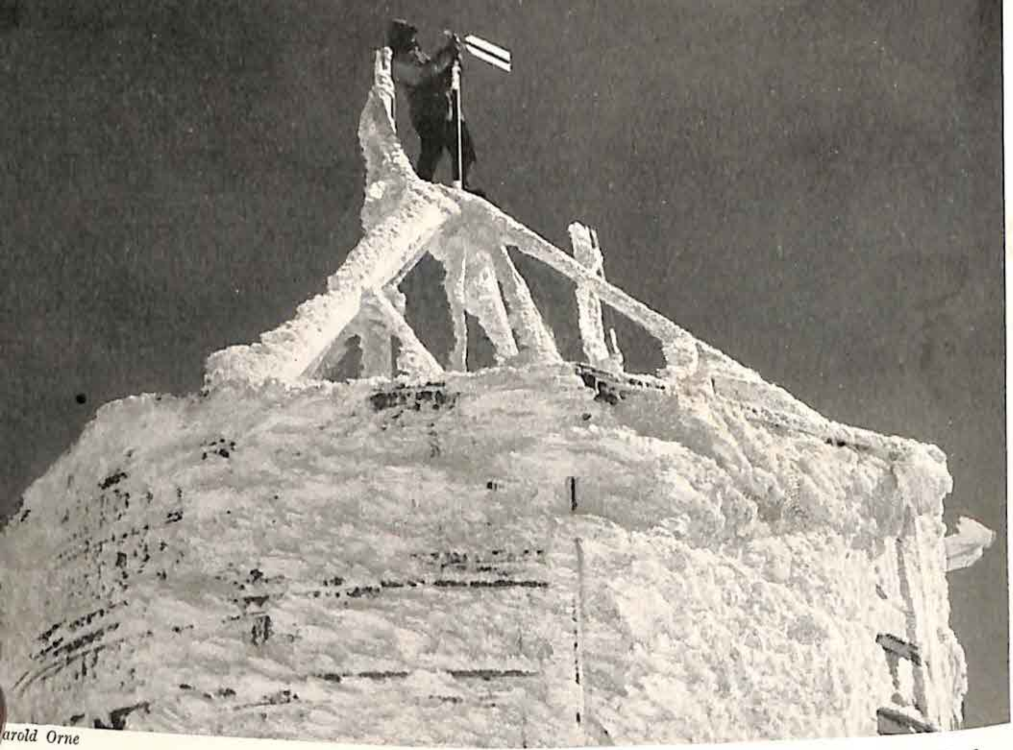

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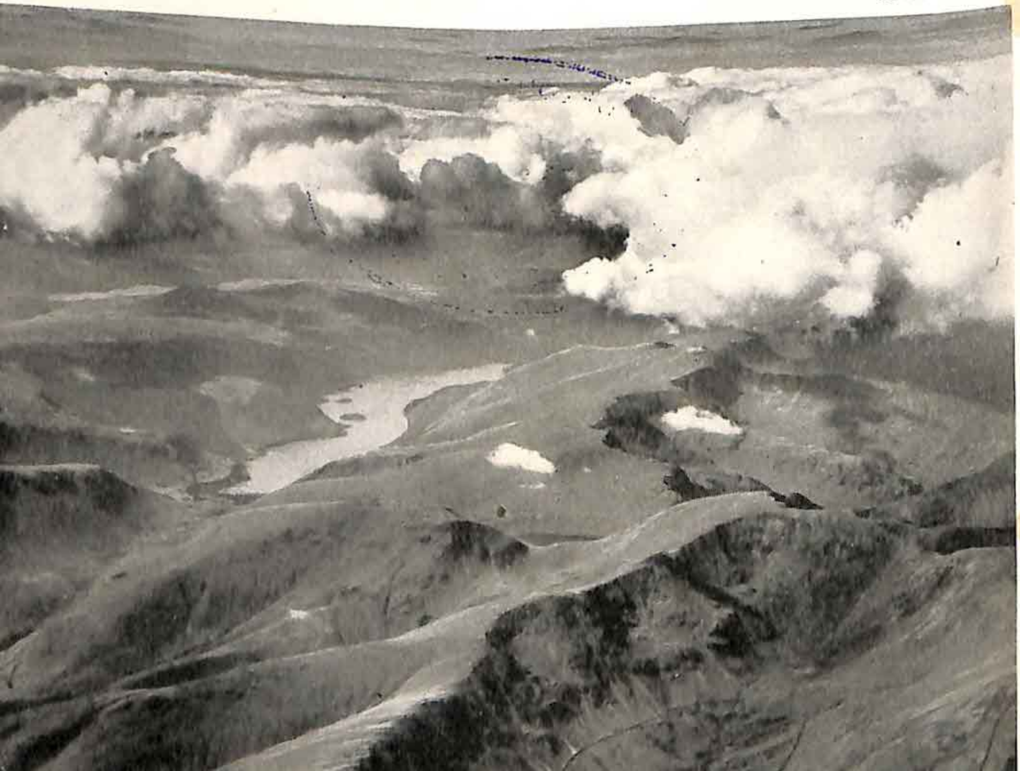

SCIENCE ON THE MARCH

UNIT THREE

THE WEATHER AND THE EARTH

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Edith Lillian Smith
Frederick L. Fitzpatrick
Charles H. Dobinson

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The first six units of SCIENCE ON THE MARCH are:

1. Air and You.
2. Water and Life.
3. The Weather and the Earth.
4. Life and Food.
5. Health.
6. Energy and Engines.

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Photos by Mirrorpic

The Weather and the Earth

How many times a day do you say something about the weather ? Sometimes, perhaps, you are just making a friendly remark to a neighbour. But when there is a biting north wind, or you expect a thunderstorm before long, you take the weather seriously.

Man has achieved a good deal of control over Nature, but he is still at the mercy of the weather. Depending upon where he is in the world it may bring him floods that wash away his home, or an avalanche overwhelming his village, or a tornado flattening his town, or a sandstorm that nearly chokes him, or a drought killing his sheep and cattle, or a tempest to wreck his ships at sea.

Truly we have reason to respect and to study these mighty forces.

Problem A : **WHY IS THE WEATHER CONSTANTLY CHANGING ?**

Scientists still have much to learn about the causes of weather changes. They have discovered, however, many of the laws that govern weather. By finding the answers to the four questions in this problem you yourself can learn at least some of the reasons for the constant change.

Problem A : Why is the Weather constantly Changing ?

Question I. **How do Weather Men study the Weather ?**

Why need men undergo the hardships of living at the tops of mountains, through intensely cold winters with frequent storms, to keep records of the weather, as the man in the first picture in this book is doing ?

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Not only the few men at such lonely stations as this, but a whole army of observers work all the time. At many stations the workers have the finest instruments modern scientists have been able to invent. But many thousands of other people, such as teachers, farmers, and housewives, work without pay in all parts of the world. They send daily reports to near-by stations.

What are all these weather observers reporting? They record and report the direction and speed of the wind; the temperature and pressure of the air; the hours of sunshine; the amount of rain or snow. It is these things that make up weather.

You may like to keep a simple weather record of your own. Rule a sheet of paper lengthwise into as many records as you wish to keep. Use each crossline for a day. Keep the record for several weeks.

DATE	TEMPERATURE	WIND DIRECTION	WIND SPEED	CONDITION OF THE SKY	CONDITION OF THE WEATHER

You should keep the record regularly, if possible at the same time each day, including Saturday and Sunday. To know the WIND DIRECTION, you will need to be able to see a wind vane. If none is within sight, it is possible to make one quite easily. Directions are given on page 24. You will also find there the way to estimate the WIND SPEED. Under CONDITION OF THE SKY write *Clear*, *Cloudy*, or *Partly cloudy*. Under

CONDITION OF THE WEATHER write *Fair*, *Rain*, *Snow*, *Fog*, and so on.

After you have kept the record for some time, answer the following questions *from your own observations*. In this way you will be using the true scientific method.

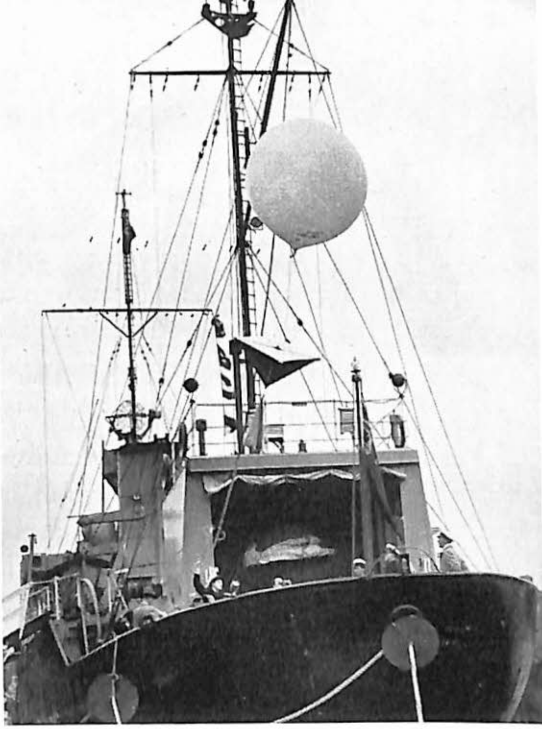

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FIGURE 3. Sending up a weather balloon from a ship.

What was the highest temperature during the period? The lowest? The range of temperature?

How many days were clear? Cloudy? Rainy? Snowy? Partly cloudy?

What was the most common direction of the wind? What was its direction when the temperature was coldest? When was the temperature warmest? Just before a storm? During a storm? Just after a storm?

Were the coldest days the clear days or the rainy days?

WEATHER OBSERVATIONS

In carefully planned positions in the North Atlantic there are now ten special weather ships. The group of nations around the Atlantic agreed to share this work. Thus Great Britain is responsible for two weather ships and shares with Holland in maintaining a third. Imagine yourself one of the crew on a weather ship at sea. One of your duties is to help in taking weather observations. Every day you send up a

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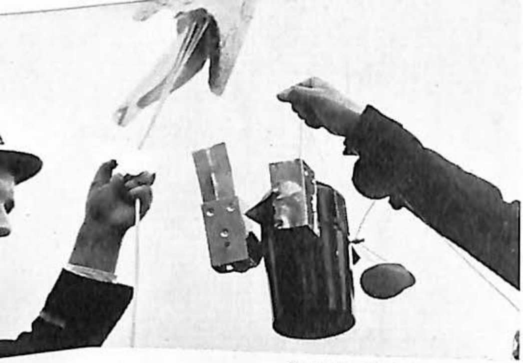

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FIGURE 4. This is the instrument carried by a weather balloon.

" weather balloon," which is really a tiny broadcasting station. The balloons are about four feet in diameter. Each one carries a lightweight radio transmitter. This sends to a receiving station on the earth's surface a constant record of the temperature, pressure, and moisture of the air where the balloon is at the time. Figure 4 shows the little instrument with its parts. It weighs about three pounds.

A change in weather may have great importance: a sudden cold spell may increase the demand for electricity over a whole country, make roads ice-bound and produce fog over hundreds of square miles. If people can be told in advance what to expect, preparations can be made to meet the difficulties. That is why weather stations endeavour to predict if snow, or fog, or a killing frost is to be expected. In the British Isles the main weather station at Dunstable sends warnings to all farmers who arrange to pay for the telegram or the telephone message. For the guidance of pilots of aeroplanes the Dunstable headquarters of the weather men is in constant telephone contact with every important airfield in the country. Indeed the safety of all flying depends largely on the weather men (or meteorologists as they are called), so they have now made a radio network linking all countries. So Dunstable continually exchanges information by radio with Paris, Rome, Moscow and the United States and Canada. Besides their work for aviation, weather stations issue gale warnings which are broadcast immediately in the radio programmes, so as to give small ships a chance to make harbour before they get into peril.

Weather stations also keep records from year to year. Have you noticed in the newspapers such a statement as this: " Hottest Whit-Monday for 29 years " ?

The result of observing or of keeping records over many years is that one gets just a little guidance concerning short periods of the year which are *likely* to be warm, or cold, or stormy. Thus country people talk of " St. Luke's little summer " for a warm sunny spell that frequently occurs in southern England around October 18th, St. Luke's Day. Dr. Alexander Buchan, F.R.S., who studied the weather a hundred years ago, as early as 1867 named six cold periods and three warm periods which tend to recur year after year in Scotland at about the same dates. Such " Buchan periods " do in fact help one a little in making one's plans. Why not look them up, and other interesting weather information, in *Whitaker's Almanack*? But the weather does not keep to any fixed programme and you should be prepared for frequent disappointment in the warm and cold periods you expect.

Some day, however, we may be able to know in advance whether to expect a dry or a wet summer. For instance, it seems that, in some parts of the world, particular weather conditions tend to occur in a year when there is an exceptionally large number of spots on the sun's surface. We know that these outbursts of special activity in the sun happen about every eleven years. But at present the evidence is not enough for us to draw any sure conclusions.

Now go on to answer the next questions, and you will find out more about the actual instruments that weather men use.

SOME THINGS YOU MAY CARE TO DO

1. Visit the nearest weather station and write a report on what you see and learn. Include something about the instruments used, where they are located, and how records are kept.

2. Read *Your Weather Service* (Published by H.M.S.O.), and report on weather warnings for farmers.

Problem A: Why is the Weather constantly Changing?

Question 2. **How do we Measure Temperature Changes?**

Is today a cloudy but fairly warm day? Or is it a bitterly cold foggy day such as some parts of England often get in November or February? Whatever the weather is, you know that you can tell how hot or how cold it is by reading a thermometer.

The most common kind of thermometer consists of a narrow glass tube with a bulb at one end and closed at the other end. Probably you have seen hundreds of them. Inside the bulb and the tube is a liquid: in thermometers which doctors use it is always the silvery-looking liquid called mercury or quicksilver. In science laboratories, too, the thermometers usually contain mercury. The height of the liquid in the tube changes as the temperature changes, because mercury, like other things, expands when it is warmed and contracts when it is cooled.

A simple experiment will show you how a liquid behaves when its temperature changes. (See Figure 5.) Pour water into a flask until it is full. To see the results, put a little colouring into the water. Red ink will do. Close the flask with a one-holed rubber stopper fitted with a glass tube about a foot long. Now heat the flask gently and watch the tube. What happens?

When you take the heat away, how does the coloured liquid behave ?

How does a change in temperature affect water ?

THERMOMETERS

If your mother asks, " How hot is it today ? " you are likely to say, after looking at the thermometer, " Sixty," or perhaps " Sixty degrees." But if you look in the newspapers you may read 60° in one place and 60° F. in another. What is this F. for ? Is 60° F. any hotter than 60° ?

The thermometer was not invented by weather men, but by a scientist who wanted to help doctors tell when their patients have a fever. His name was Gabriel D. Fahrenheit. Since then his invention has been used to find the temperature of all sorts of things. Fahrenheit marked the thermometer he invented in such a way that it showed 32° when water freezes and showed 212° when water boils.

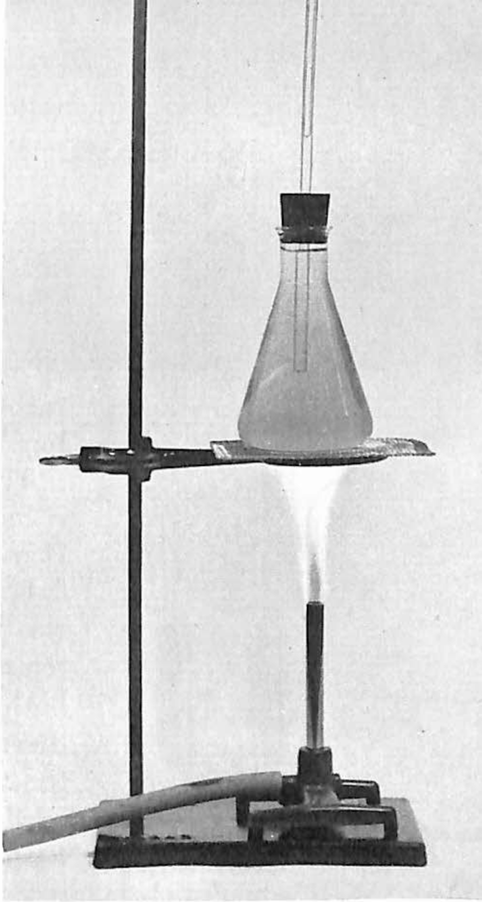


FIGURE 5. When you heat the flask of water, support it on a piece of wire gauze to keep the flame from cracking the glass.

Other men made thermometers which they marked quite differently from Fahrenheit's. For example, one commonly used in many countries and by scientists is marked 0° to show the freezing point of

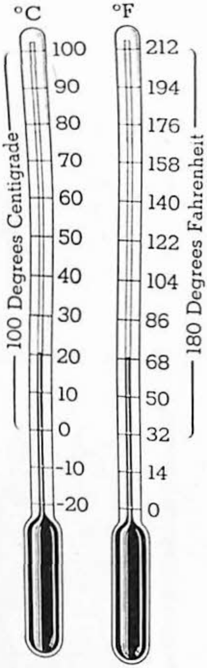


FIGURE 6. Centigrade and Fahrenheit thermometers.

water, and 100° to show the boiling point. This is called a *Centigrade* thermometer. (On the Continent this is called the Celsius scale.) Figure 6 shows how both Centigrade and Fahrenheit thermometers are marked. You see that 20° C. and 20° F. are not the same; 20° C. is rather warmer than your classroom, but 20° F. is much colder than ice.

The liquid used in thermometers is not always the silvery mercury. It may be red ink and alcohol, which is better than mercury in very cold weather because it freezes at a lower temperature. Weather men use both the mercury and the alcohol thermometers. They need to know the temperature at all times. They need to keep a complete record. In Figures 7 and 8 you will see pictures of some of their instruments. To be sure that they are shaded from the sun, the thermometers are usually kept in shelters made especially for them.

You may have noticed in weather reports that the highest and lowest temperatures of the day are given. These are obtained by special thermometers, called *maximum and minimum* (greatest and least) thermometers. The two which are shown in Figure 7 are used to record the hottest and coldest temperatures of the day.

The instrument in Figure 8 is a *thermograph*. This name means "recorder of heat." The picture shows one with the inner parts taken out of the case. The drum moves by clockwork. The pen is connected with

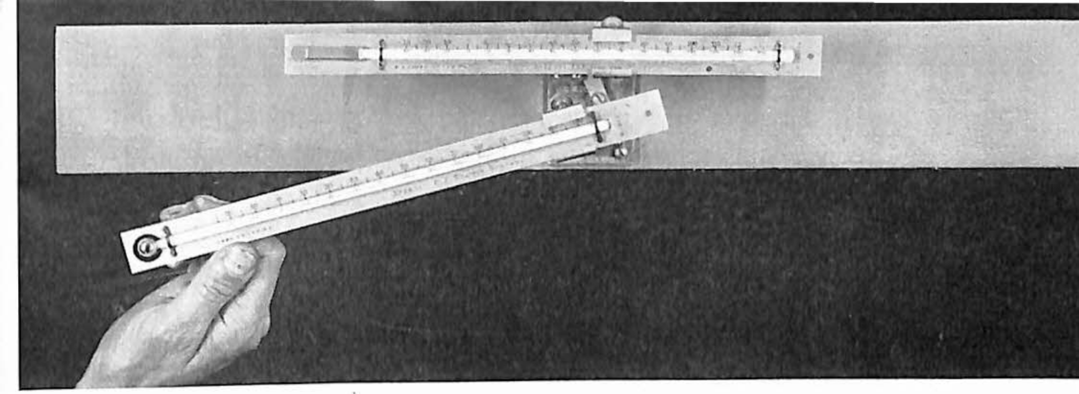


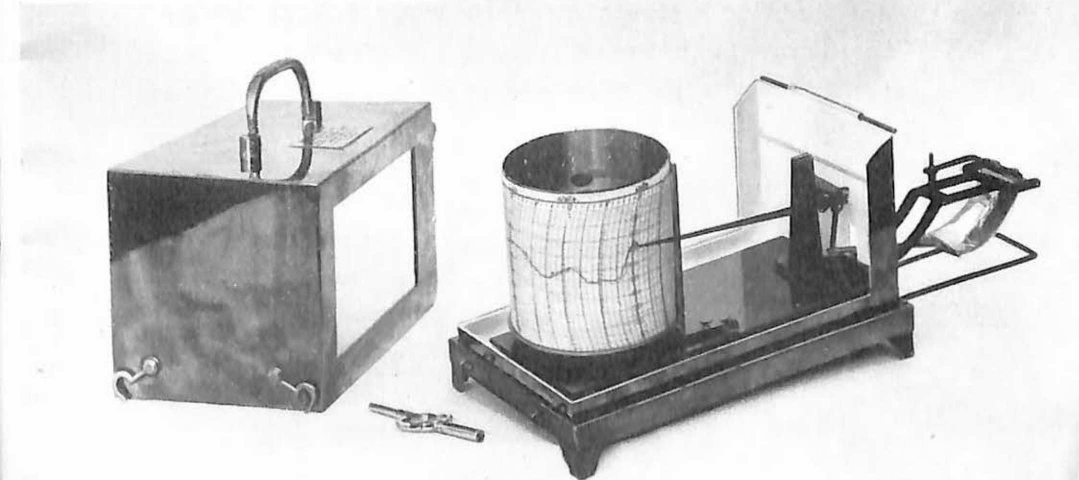
FIGURE 7. Maximum and minimum thermometers are usually fixed in a horizontal position. Do you know why ?

a curved metal bar which expands when heated and contracts when cooled, causing the pen to move up and down on a sheet of ruled paper. Thus, a continuous record of temperature changes is kept.

SOME THINGS YOU MAY CARE TO DO

1. Try to keep an hourly record of outdoor temperature for at least six hours at a stretch. You may wish to do this at home on a Saturday. Perhaps you can keep the record for twelve hours. How many degrees did the temperature change ? What was the warmest hour ? The coldest hour ? Compare your records

FIGURE 8. The thermograph keeps a constant record of temperature.



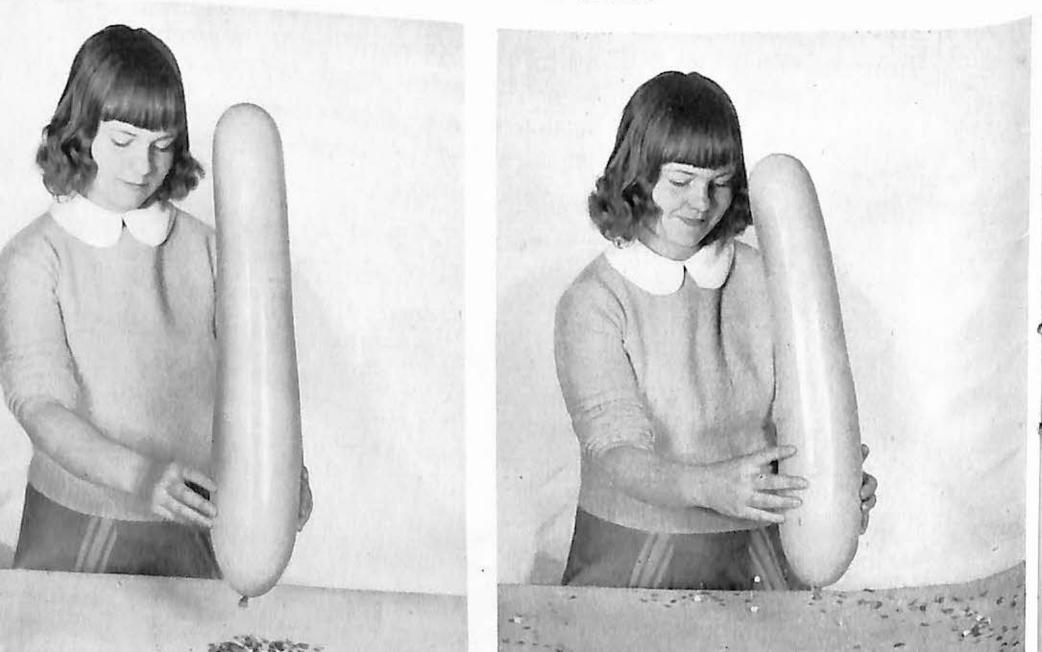
with those of others in the class. Are you able from these observations to come to any conclusion about daily range of temperature ?

2. Keep a temperature record for several days. Are you then able to reach any conclusion about daily range of temperature ?

3. If you live near the sea, or a lake, or a river, see if you can take the temperature of the water twice a day for several weeks. Does the temperature of the water change more rapidly or more slowly than the temperature of the air ?

4. An air thermometer may be made by using a large bottle, and a stopper fitted with a glass tube. Draw a very small amount of red ink or coloured water into the tube, so that it forms a small bubble just above the stopper. Place a paper scale behind the glass tube. When you hold your hand against the bottle, does the liquid move ? In what direction ? Does the air expand when it is warmed, as liquids do ?

FIGURE 9. How does this experiment help you to understand why the wind blows ?



Question 3. **Why does the Wind Blow ?**

What is this wind, that we cannot see, but can feel and hear so plainly ? It is just air—air moving from one place to another. " Why does it move ? " you may ask. Scientists say it is because of differences in pressure. You know that air weighs something, and is a real substance. You may remember that the pressure of air at sea level is about fifteen pounds per square inch. Notice the word " about," which suggests that air pressure is not always the same, even at sea level.

To show how air under pressure can cause wind, you may use a long balloon and some confetti. (See Figure 9.) If you blow up the balloon as full as you can, you have in it some air, the pressure of which is high. Now hold the balloon over some confetti you have scattered on a table-top. When you release the air, the confetti is blown away.

In what direction does the air blow from an area of high pressure ?

In what respects are the conditions of this experiment different from those in the atmosphere ?

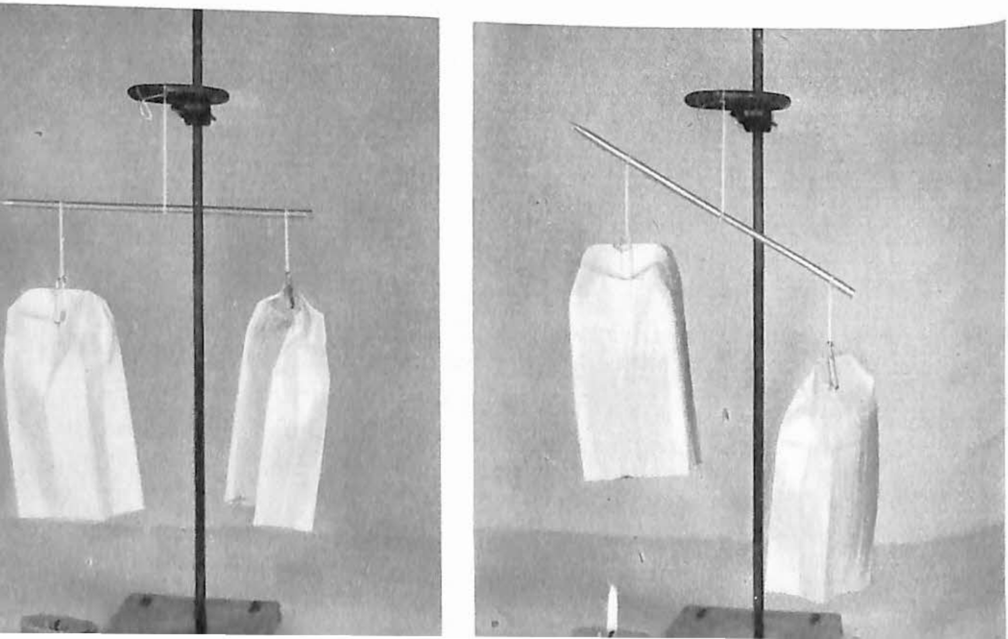
WINDS ARE THE RESULT OF DIFFERENCE IN AIR PRESSURE

Winds blow from a region of high air pressure to a region of low air pressure. The speed, or *velocity*, of the wind depends upon the difference in the pressure. You know that the speed of a stream of water depends partly upon the difference in height between its source and its mouth. A mountain stream, for example, rushes fast down its course because the source is high up above the mouth, and the slopes of the mountains are steep. On the other hand, a river that winds across a nearly level plain moves slowly. So it is with the streams of air that we call *winds*. The movement of air may be so gentle as barely to cause the leaves of trees to rustle, or it may be so violent that we call it a *gale*. In the first case the air is moving between places where the pressure is almost the same; in the second case the air moves from a place where air pressure is high to a region where it is much lower.

Why the pressure varies. Scientists are not sure that they have learned all the causes of unequal pressure of air. Two common causes, however, are known. The first is heat. You are familiar with the action of heated air. You have often seen sparks fly *upward* from a bonfire. You know that heated air moves upward. If it did not, it would not be much use to build chimneys above fires! Heated air is lighter than cooler air, and thus exerts less pressure.

Figure 10 shows one way of proving that hot air is lighter than an equal volume of cool air. The two

FIGURE 10. Be sure the two bags of air balance before you start the experiment.



paper bags are balanced, with their open ends at the bottom. Then if you hold a lighted candle under one bag, at the same time holding it with your other hand, you will heat the air in it. When you let go with your hand, this bag will rise because it is now lighter than the other bag of air.

How does this experiment show one cause of a wind?

A second cause of differences in air pressure is the presence of water vapour in the air. If you could compare the weight of a quart of water vapour with the weight of a quart of air, you would find that the water vapour is lighter. Air with considerable water vapour in it presses down, then, with less weight than air with only a small amount of water vapour in it.

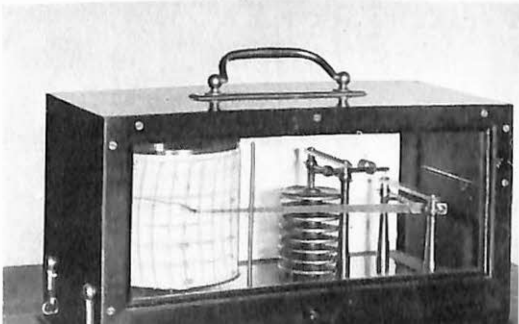
We have found two reasons why the air pressure in one place may be less than that in other places. But what has this to do with our question about wind? We must remember that air is free to move. It is not fixed in a certain place, as rocks are fixed. So when a certain mass of air is pressing down harder than the air near it, it pushes that air aside. The moving air is the wind.

Barometers. Weather men measure air pressure with instruments called *barometers*. They are very useful, not only in weather stations, but in our homes, on board ship, and in aeroplanes.

In weather stations the records of changing air pressure are kept by means of a special instrument called a *barograph*. The word means " pressure recorder." One such recorder is shown in Figure 11.

Let us not forget that our question was : " Why does

FIGURE 11. On this barograph the pen makes a continuous record on a revolving drum.



the wind blow ? " To answer it we have had to learn about air pressure, and why it is not always the same. Remember that whenever there is a difference in air pressure, a wind begins to blow.

SOME THINGS YOU MAY CARE TO DO

1. Keep a record of barometer readings for several days. How much do they vary ? It is more interesting if you record the readings in the form of a graph.

2. Notice the direction *from* which the wind is blowing today. Is the air pressure in that direction higher or lower than that shown by your own barometer ? Find a newspaper which publishes forecast charts and check your answer by looking up the pressure expected at some place in that direction. Note that forecasts predict the pressure at a definite time, say twelve noon. Also it is possible that the pressures may not have turned out as the weather men expected.

3. Keep a record of wind observations for at least a week. Make your observations twice a day. A table like this is a convenient way of keeping the records :

DATE	HOUR	WHAT I NOTICED ABOUT THE WIND

FIGURE 12. What instruments can you recognize ?

Photos by Keystone Press Agency, Ltd.

Question 4. **What have Winds to do with Weather Changes?**

No doubt you have already noticed that weather conditions depend a great deal upon the direction of the wind. When the wind blows from the south, the weather in Britain is likely to be mild, even hot in summer. A north wind usually brings cooler weather. What sort of weather do people in the British Isles usually associate with winds from the south-west? Can you explain why the direction of the wind brings about the changes in the weather?

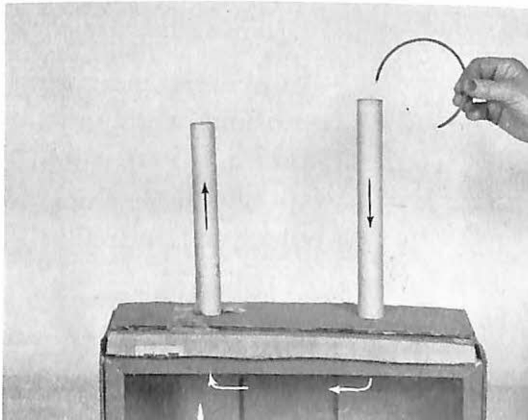
Wind, we have learned, is air in motion. But what sets it in motion? In answering Question 3 you learned that differences in air pressure started winds. An experiment with a "wind box" will show you *one* of the causes of air movement.

Use a box at least a foot long. Turn it on its side and fit a sheet of glass in place of the cover. Bore two holes of just the right size for lamp chimneys or cardboard tubes to fit. Light a short candle and place it under one of the chimneys. Be sure that the glass side fits tightly.

Now you are ready for the experiment. By holding "smoke paper" (paper soaked in a solution of potassium nitrate and dried), or a twisted piece of smoking wax paper, over one of the chimneys, you may trace the air currents by the smoke.

In which chimney is the air moving upward? Downward? How does the air move in the box?

FIGURE 13. What is the reason for the movement of the air as shown by arrows?



This experiment shows that heated air moves upward because it expands and becomes lighter. It does not press down with as much weight as cooler air. But we do not call this upward-moving current " the wind." The flow of air *along* the ground is the wind. It moves from regions where pressure is high to regions where the pressure is low. The greater the difference in pressure, the faster the air moves, or, in other words, the greater the speed of the wind.

We shall not try to explain all the reasons why the pressure of air varies. Figure 14, however, shows how the weather depends on these air movements.

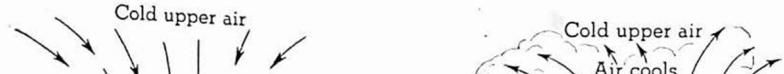


FIGURE 14. Weather conditions in two towns on the same day.

Suppose you were in Town X on a day when weather conditions were as shown in the left hand side of the diagram. You would be enjoying clear, cool weather with cloudless skies. But if you were in Town Y, about five hundred miles away, on that same day, your outdoor fun might be spoiled because of the rain. The upward currents of warm, moist air, reaching the cold upper air, would produce clouds, followed by rain.

What conditions would make the air rise over Town Y?

What reasons would you now give for the constant changes in the weather?

SOME THINGS YOU MAY CARE TO DO

1. *Wind observations.* What is the *direction* from which the wind is blowing today? Is it blowing from a region which is usually cooler than yours? If so, has it brought you cooler weather?

About what is the *speed* of today's wind? You can tell about how fast the wind is blowing by observing smoke and trees. In a *calm*, smoke rises straight up, and you can see no motion of leaves. In a *light air*, when the speed is between one and three miles per hour, smoke drifts, but wind vanes do not move. In a *light breeze*, when the velocity is between 4 and 7 miles per hour, you can feel wind on your face and see leaves rustle. In a *gentle breeze* (8 to 12 miles per hour), leaves and twigs are in constant motion and light flags stand out. A *strong breeze* blows from 25 to 31 miles per hour, setting large branches in motion and making umbrellas hard to manage. In a moderate gale (32 to 38 miles per hour), whole trees are swaying.

2. *Making a wind vane.* Wind vanes may be of many shapes. It is only necessary that they turn easily, and that one end has more surface exposed to the wind than the other. One of the simplest vanes is shown in Figure 15.

Make the vane either of wood or of metal, about two feet long, with the blade at least four inches wide. To make it swing freely, set it into a large spool which

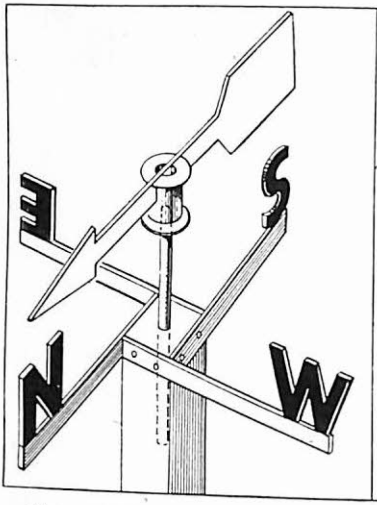


FIGURE 15. It is easy to make this vane which is just a balanced arrow.

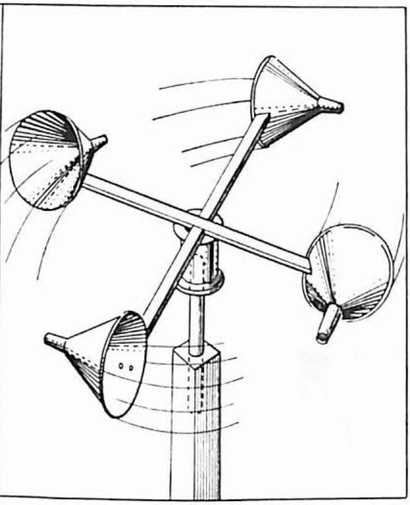
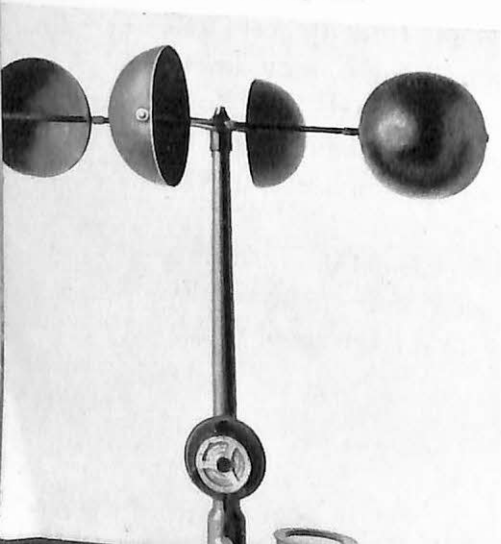


FIGURE 16. Four small funnels make this wind-speed recorder.

has a slot cut in the top. To make the vane swing freely, place a piece of brass at the bottom of the slot before you glue the arrow into position. For a support fasten a small steel dowel rod in the top of a pole, so that the hole in the spool will fit loosely over it. It is a good plan to smear a little grease on the rod to prevent friction.

FIGURE 17. An anemometer with a recording dial.



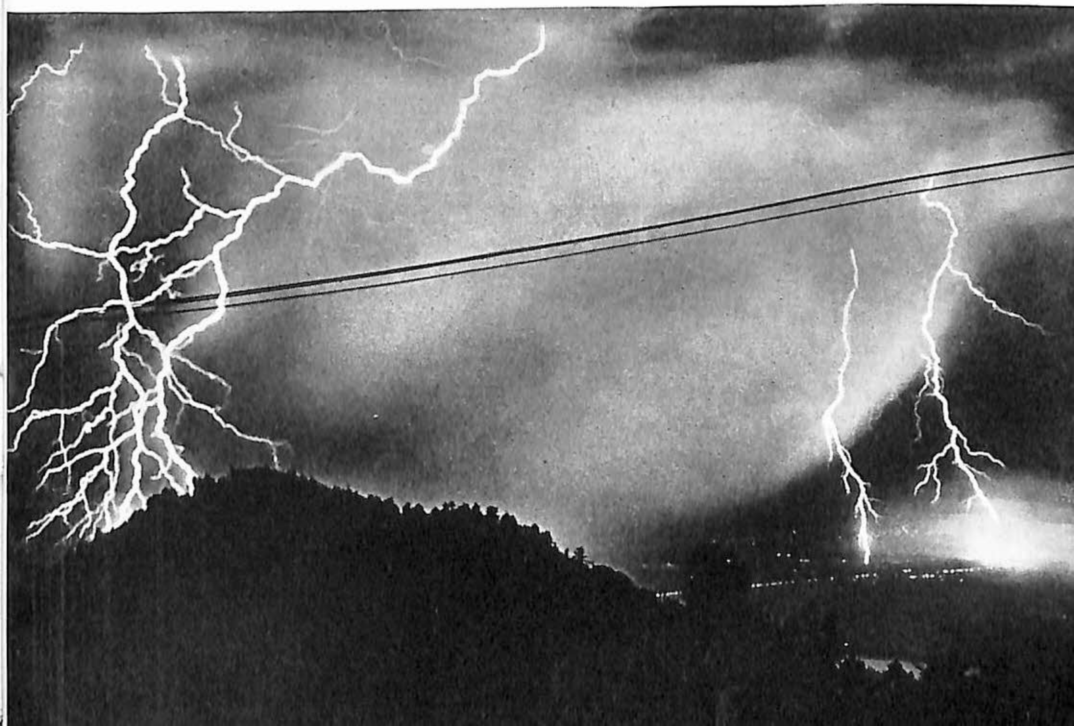
The tip of the arrow will swing around and point to the direction *from* which the wind blows. To be sure what the direction is, you should provide the vane with four arms to show the points of the compass, north, east, south, and west. Cut the letters from sheet metal and fasten them at the ends of wooden or metal rods. Use a compass to fasten them correctly in place.

3. *Making a wind-speed recorder.* One of the instruments used at a weather station is a device to tell how fast the wind is blowing. It is called an *anemometer.* As you see in Figure 17, this device has a dial to register the exact speed of the wind.

The wind-speed recorder shown in Figure 16 has no dial, but you can estimate the speed of the wind by noticing how fast the cups spin around. You can make it by fastening with fine wire nails four small funnels to the ends of two rods about two feet long. The holes in the funnels are plugged.

To make sure that the anemometer will turn freely, screw a piece of brass across the end of the large spool, and fasten the rods to this end. The dowel on which the spool turns should be rounded and well greased.

FIGURE 18. A thunderstorm at night. Can you suggest what the straight lines of lights may be ? Would you agree that this photograph has been taken from high ground ?



Problem B : WHY DO WE NOT ALWAYS HAVE FAIR WEATHER ?

Has your radio listening sometimes been interrupted by crackling and sizzling noises ? Did you know that these " atmospherics " are due to lightning flashes ? Nowadays thunderstorms can be traced by radio direction-finders as far as 1500 miles. And rain, provided the drops are not too small, can be " seen " on a radar screen up to 70 miles away.

How exciting it is to be in the midst of a thunderstorm ! The blinding flashes of lightning, the crashes of the thunder, the sudden drenching rain may be a frightening experience. But the rain that falls, either in a thunderstorm or in an ordinary rainstorm, is essential for life on the earth. Without rain our land would be a desert.

Where does the rain come from ? From the air, to be sure. No doubt you know that our atmosphere contains water, in the form of vapour. As long as the water in the air near us *remains* in the form of vapour, the weather is likely to be fair. But when the vapour changes to drops of liquid, then our weather changes.

Problem B: Why do we not Always have Fair Weather ?

Question 1. How does the Amount of Moisture in the Air Change ?

Would you like to have a bouquet of flowers which will let you know when it is going to rain ? You may do so if you can get (or make) some tissue-paper flowers, half of them pink and the other half blue. Then get a small quantity of cobalt chloride (which you can buy at a chemist's), and dissolve it in a little water. Dip the flowers in the solution and let them dry. It may be necessary to dip them several times, letting them dry each time.

The secret of this floral " barometer " is that certain chemicals change under the influence of moisture. Cobalt chloride is one which does. In moist weather the flowers will keep their pink and blue colours. In dry weather the pink flowers will turn purple and the blue flowers will be greenish. Of course this barometer will not help to foretell rain unless you keep it out-of-doors.

How long before the rain does the floral barometer show change of colour?

Moisture in the air. Your comfort depends largely on the amount of moisture in the air. In winter a damp day causes you to feel chilly because the moist air can conduct the heat of your body away more quickly than dry air can. In summer a damp, " muggy " day makes you uncomfortable because perspiration does not evaporate quickly from the surface of your skin. Clothes will not dry well on such a day. Wood swells and drawers stick.

Possibly you play the violin. If so, you know that the horsehairs in your bow are looser in wet weather than in dry weather. Human hairs act the same way. Girls know that naturally curly hair curls more on damp days and straightens out on dry days. This is because each hair lengthens a little when it is moist.

We may show by an experiment how a hair changes in length. A small weight is tied to one end of a hair. The other end is tied to a rod on a retort stand, as shown in Figure 19. When water is boiled under the hair, the moisture rises into the air and affects the hair.

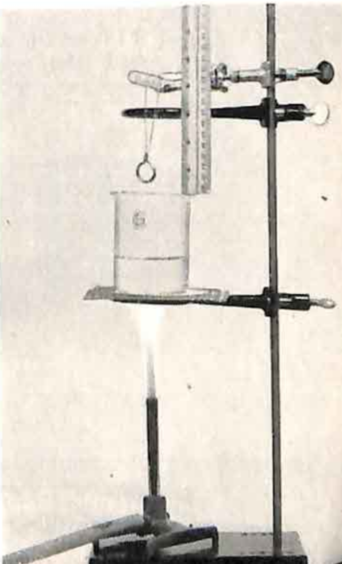


FIGURE 19. When the water boils the weight tied to the hair drops a little. Why?

How does the position of the weight show a change in length of the hair?

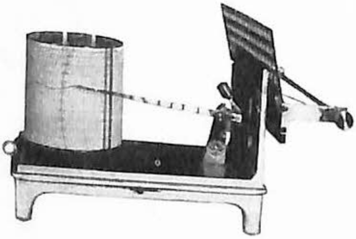
Because a hair lengthens when moist, it is used in an instrument called a *hygrometer* (moisture measurer). Many weather stations keep a continuous record of air moisture. The instrument shown in Figure 20 reminds you a little of the other recording instruments you know, because it has a revolving drum to keep the record for a week at a time.

You may have heard people speak of a "wet wind." Air which contains droplets of water feels wet, of course. If the wind blows towards a place which is warmer, however, it may change to a "dry wind." This is because, when the air becomes warmed, the droplets in it turn to water vapour.

The amount of *moisture* in the air is called the *humidity*. Weather men must study the humidity of air just as carefully as they study temperature or pressure. There is a very close connection between the temperature and the humidity of air. The warmer the air, the more water remains in the form of vapour. As air cools some of the vapour *condenses* to liquid water.

Moreover damp air acts like a thick blanket over the earth. This is because the earth is always giving off, in the form of radiations, some of the heat it has obtained from the sun. These radiations can pass through dry air, which is one of the reasons why nights are cold in hot deserts. But they can hardly pass at all through damp air and this makes damp tropical regions very uncomfortable for Europeans.

FIGURE 20. On this hair hygrograph the relative humidity is shown to vary from hour to hour.



SOMETHING YOU MAY CARE TO DO

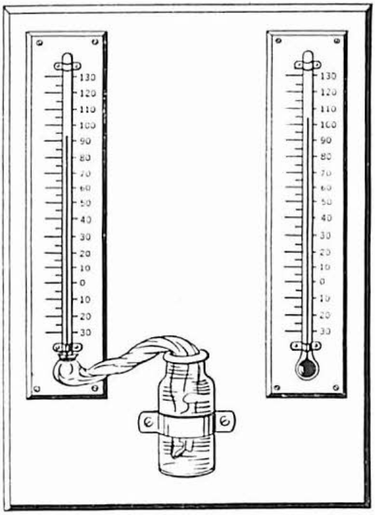


FIGURE 21. A useful weather instrument you can make.

Make wet- and dry-bulb thermometers for showing humidity. Attach two small thermometers to a board or strong cardboard. One bulb is kept dry; the other is kept wet by means of a wet cloth wrapped around the bulb as shown in Figure 21.

The way to use this device is to fan it vigorously for a moment or two and then read the temperature on both the dry-bulb thermometer and the wet-bulb thermometer, noting the difference between the two. The relative humidity of the air is the percentage of moisture which it actually contains compared with what air at that temperature *can* contain. To find it, you must use a table which scientists have worked out.

TABLE SHOWING HUMIDITY IN PERCENTAGES

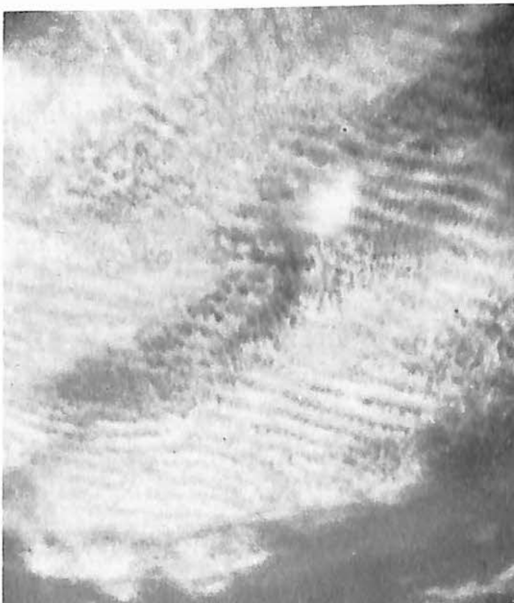
Dry-bulb Temp.	Difference between Dry-bulb and Wet-bulb Temperature																			
	1·0°	2·0°	3·0°	4·0°	5·0°	6·0°	7·0°	8·0°	9·0°	10·0°	11·0°	12·0°	13·0°	14·0°	15·0°	16·0°	17·0°	18·0°	19·0°	20·0°
65°	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21	17	13
66°	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15
67°	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23	20	16
68°	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17
69°	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25	22	19
70°	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20
71°	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27	24	21
72°	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22
73°	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29	26	23
74°	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24

In the experiment to show the formation of dew you learned that water vapour in the air would change to liquid when the temperature was lowered to a certain point. You might conclude from this one experiment that vapour turns to liquid when the temperature falls to the dewpoint. Thus you would account for dew forming. But how about clouds?

It is easy to prove that expanding air grows cooler. If you let some air out of the tyre of a motor-car or bicycle, holding a thermometer at the valve meanwhile, you will see the mercury go down. The air in the tyre is under pressure, of course. When it escapes, it expands and grows cooler. In somewhat the same way, when air rises it is under less pressure, and it expands and grows cooler. Water vapour then turns to droplets of liquid water.

Sometimes the moisture in the air is in such tiny particles that it cannot be seen. We are conscious of the dampness because we feel it rather than see it. At other times the particles of water may be seen, but they are so small and light that they float in the air. Millions of them together produce either *fog* or *clouds*. Fog is a cloud near the ground or the surface of water. Both fog and clouds form around particles of dust floating in the air.

FIGURE 23. These clouds are about five miles above the ground. Do you think they are made of water or ice?



When water vapour condenses at temperatures

If the dry-bulb reading is 68 degrees, for example, and the wet-bulb reading is 58 degrees, the difference is 10. Follow in the table the line across from 68° until it meets the line down from 10°, and you find the figure 55. This shows that relative humidity is 55 per cent. This is a very good percentage for health and comfort.

Problem B: Why do we not Always have Fair Weather ?

Question 2. **Why does Water Condense in Different Forms ?**

On calm and clear summer evenings, grass becomes wet, although there has been no rain. People say, " The dew has fallen." But does the dew actually *fall* ?

During the day the sun's rays have warmed the ground and made the air above it warm. When the sun sets, the ground cools and chills the air above it until the water vapour in this layer of air condenses.

An experiment will help you to understand what happens. Put some cold water into a polished metal cup. Take the temperature of the water by stirring it with a thermometer. Then add chips of ice until you see moisture appear on the outside of the cup. Note the temperature. This is the *dewpoint* of the air in the room.

How much of a drop in temperature was necessary before moisture appeared ?

Where did the moisture come from ?

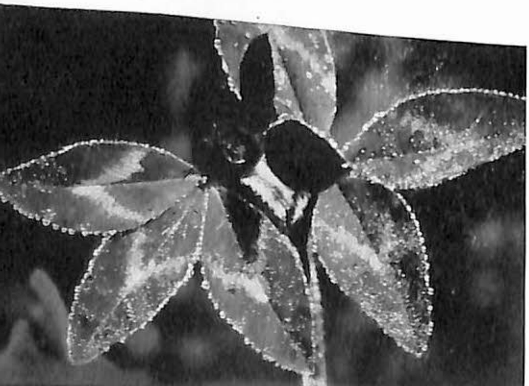


FIGURE 22. Morning dew on the leaves of a plant. Where did the dew come from ? Can you suggest any reason why the dew-drops seem larger and more numerous on the edges of the leaves ?

below the freezing point, it changes to the solid form of water rather than to the liquid form. Then you get frost instead of dew. Clouds that appear high up in the atmosphere where it is very cold, like those in Figure 23, are made of tiny particles of ice.

SOME THINGS YOU MAY CARE TO DO

1. Make a collection of pictures showing different forms in which water condenses.

2. Can you answer these questions, from what you have learned in this lesson ? (*a*) Why is it possible to " see your breath " in winter ? (*b*) What is the explanation of the almost constant fogs off the coast of Newfoundland ? (*c*) Why do fogs often disappear as the sun gets higher in the sky ? (*d*) Why do Bedouin Arabs who live in oases in hot deserts always travel with warm blankets ?

Problem B: Why do we not Always have Fair Weather ?

Question 3. **Why does it sometimes Rain ?**

Rain, as you know, is the fall of drops of water through the air. The following experiment will help you a little to understand why rain falls, although the conditions of the experiment are in some ways quite unlike those in nature.

Support over a flame a glass beaker, about one third full of water. Heat the water carefully. When it is boiling, insert a *cold, dry* glass funnel over the beaker. Heat for another minute or two, watching carefully what happens. Do drops of water run down the glass ? Where do they form ?

In this experiment, what causes the water to evaporate ? What causes the vapour to condense ?

In what two ways are the conditions of this experiment unlike those which cause rain to fall ?

Rain. Have you ever wondered where all the water that falls from the clouds has come from ? Of course, you think first of the vast water surfaces of the oceans of the world. Remember that every minute, night and day, some evaporation is going on, the amount during the day being greater than that during the night because the day is usually warmer. Then there is the water that is released by green plants, which is a surprisingly large amount. One grass plant, for example, may give off in a day more than its own weight of water. An acre of wheat in England will give off nearly 500 tons of water during the time it is growing.

We do not expect rain unless we first see clouds. Scientists say that the droplets that make them up are so small that a hundred and twenty-five of them in a row would measure only one inch. They are so light that the most gentle current of air holds them up. As more and more droplets condense, however, they unite to form drops which finally are heavy enough to fall through the air.

Figure 24 shows you several steps in the coming of a rainstorm.

(A) Warm, moist air rises because heavier air pushes in under it.

(B) As the moist air rises, it expands and becomes cooler. This causes the vapour to condense on particles of dust and form a cloud.

(C) Clouds are blown along by the wind.

(D) When the drops of water in the cloud are heavy enough, they fall as rain.

(E) The rain cools the air, thus causing downward currents.

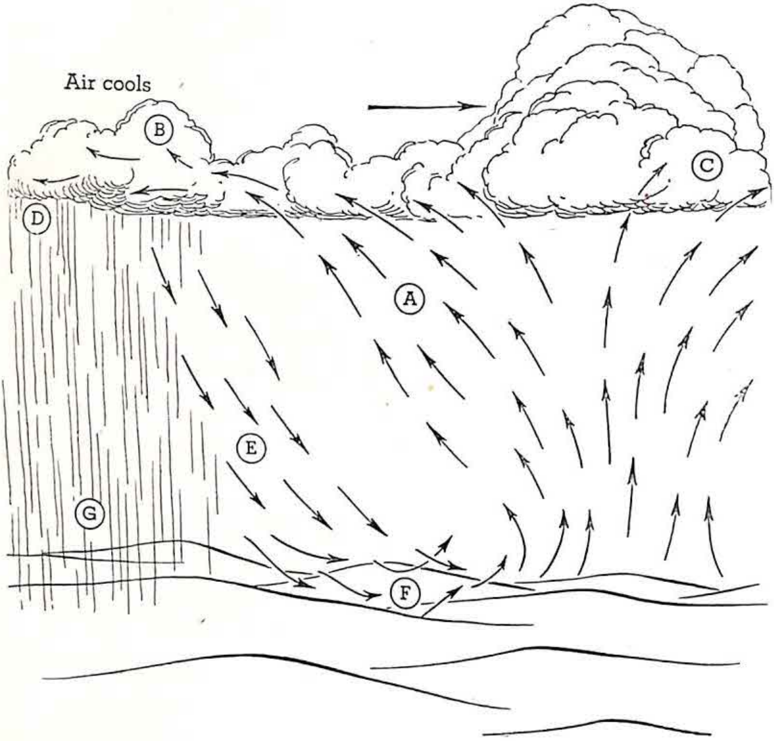


FIGURE 24. Why it rains.

A. Warm, moist air rising.
B. Air cools at height, and its moisture forms a cloud.
C. Cloud carried forward many miles by spreading winds.
D. Raindrops condense and fall.
E. Air currents forced down by rain.
F. Gusts of wind due to irregularities of earth surface.
G. Heavy rain follows gusts of wind.

(F) The air streams form gusts of wind that blow over trees, hills, and rooftops.

(G) Heavy rain follows the gusts of wind.

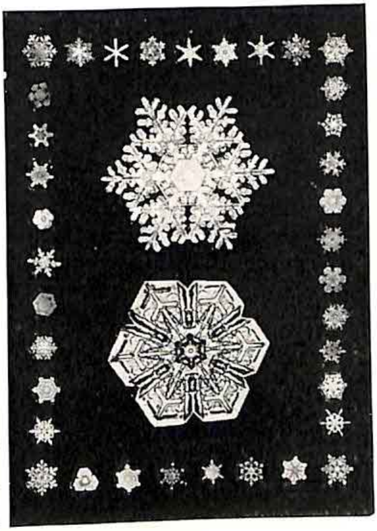
Snow and ice. Snow is the most beautiful of all the forms in which water may condense. An American scientist made a collection of nearly five thousand photographs of snow crystals, and no two were alike! A few of them are shown in Figure 25.

When a strong wind begins to blow from the north-east in winter time people in the British Isles are likely to experience some very cold weather. There may well be snow, especially on mountains and hills. In Canada, too, and in the United States, a north-east wind in winter is a bad sign.

A blizzard is a very severe snowstorm. We have all read of the heroism of Captain Scott and his companions who died in a blizzard which lasted for days when they were trying to return from the South Pole. In some parts of the United States, such as the upper part of the Mississippi Valley, blizzards are common, though not so bad, of course, as in the Antarctic. A gale of wind, intense cold, and drifting powdery snow mark their coming. Sheep on the mountains, as in Wales or on the Pennines, and cattle out on open range as in the Mississippi valley, both suffer terribly in such storms. On the Pennines deep snowdrifts gather in the mountain hollows and on the Mississippi plains the grass is covered with snow perhaps several feet thick. The animals wander bewildered and blinded. It is not surprising that many starve to death before their owners can find them.

FIGURE 25. Snow crystals.

Ewing Galloway



In some countries there are "ice-storms" which may do much damage and may almost stop road traffic. To produce an ice-storm there must be warm air above and cold air below, which is the opposite of the usual situation, but it sometimes occurs. The water vapour condenses in the form of rain, but it freezes when it strikes the cold area near the ground.

Harmful as snowstorms and ice-storms may be, there is another side to the story. In some parts of the world the annual water supply depends upon a good fall of winter snow. Snow also forms a blanket over the earth which protects the plants under it. Loose snow has a large amount of air in and between the flakes. Air is a poor conductor of heat, so the temperature of the ground remains fairly constant, no matter how much change there may be in the air temperatures. It is not so much cold weather that kills the plants in our gardens as frequent changes from cold days to warm, and then to cold again.

You can now see not only some reasons why we do not always have fair weather, but some of the advantages of storms.

SOME THINGS YOU MAY CARE TO DO

1. Devise a way of measuring the amount of rain that falls during a storm. Try it out, and compare results with those of others in the class.
2. Try to find out where weather records are kept for your region. If you are allowed to examine the records see if there have been any destructive rainstorms or snowstorms in recent years. Also calculate the average annual rainfall over the last ten years.
3. Place some chipped ice and salt in a glass. Do crystals condense on the outside from the water vapour in the air ?

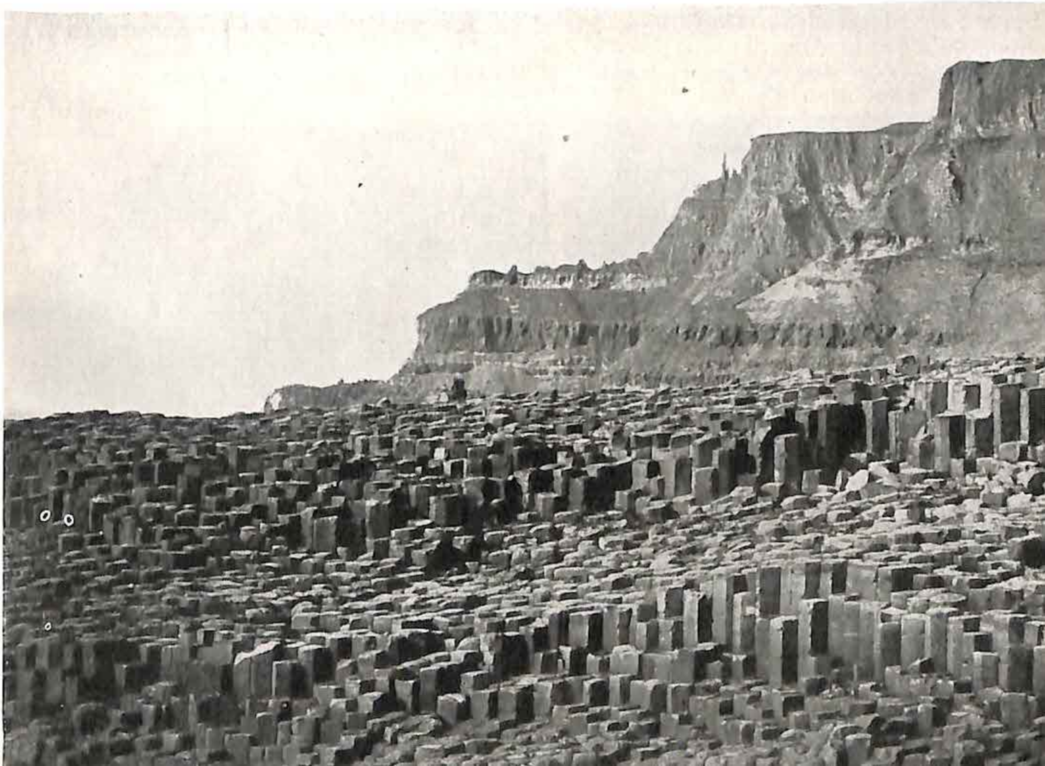
Problem C: **WHAT ARE ROCKS AND HOW ARE THEY CHANGED?**

Millions of years ago there was probably no sea separating northern Ireland from Scotland. Instead, both doubtless formed part of a large land mass which extended northwards and westwards towards Iceland.

The part of this land now forming northern Ireland seems to have been flat and low-lying, perhaps resembling Holland of today. There were plants and animals living on this land, though man had not yet appeared on the earth. But the land did not remain unchanging. After a series of occasional earthquakes, perhaps at intervals of ten years or more, great cracks appeared. Through these cracks, which were scores of miles long and possibly hundreds of feet wide, vast quantities of molten rock poured out, like lava from

FIGURE 26. The Giants' Causeway on the coast of northern Ireland. The pillars are hexagonal columns of basalt rock cooled from molten lava.

Lawrence of Dublin

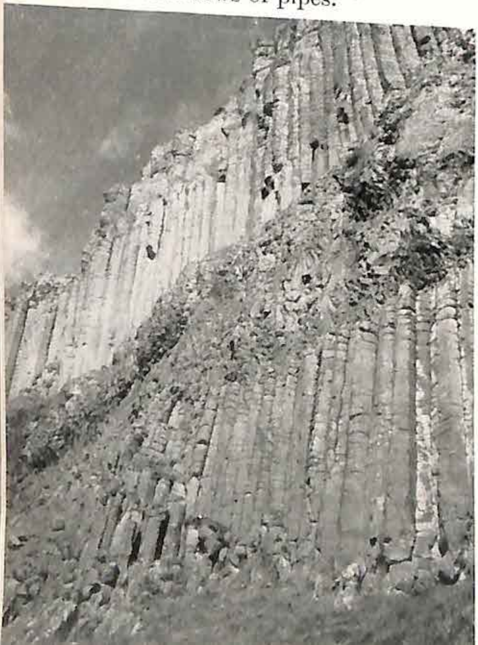


a volcano but on a scale much more immense. These gigantic flows covered thousands of square miles of land. Following one another in succession over perhaps forty or fifty years, they eventually buried the land surface beneath a hundred feet or more of the black rock which we call basalt.

Then for a long period, certainly for centuries, this rock was exposed to wind, rain and sun. Thus the surface decomposed to form soil in which sub-tropical plants established themselves. Animals and insects came in from adjoining regions and much of the area was covered with forest, including trees with trunks five or six feet in diameter.

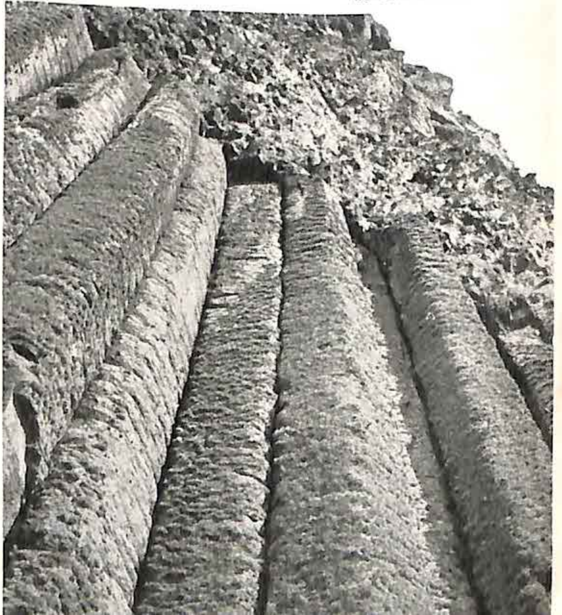
Then once again the orderly development of things was interrupted and vast new outflows of molten basalt appeared, overwhelming the forest and leaving few remains, save perhaps where rivers and lakes prevented the plants from being completely turned to cinders. These second lava flows are about one hundred feet thick.

FIGURE 27. Some of the "Organ Pipes," hexagonal columns of basalt at the Giant's Causeway. Note the irregular basalt between the two rows of pipes.



A closer view of some of the hexagonal columns of basalt. The roughness is due to lichen growing on the rock.

J. Allan Cash



Once again the surface of the solidified rock gradually became converted into soil ; once again plants and animals re-established themselves, and once again these were covered by flows of lava. Such traces of plants as remain are found as coaly fragments in a thin bed of red earth. Above this is a third thick layer of basalt. The story of the whole earth is one of constant changes, though not all as dramatic as that of the Giant's Causeway.

To avoid confusion, scientists apply the name *rock* to any material which makes up layers of the earth's crust, whether it be hard or soft. So, to a scientist, sand, clay and gravel are forms of rock, just as much as the hard black basalt which was once molten lava. Thus, whether the place where you live is a flat plain, a rough highland, or rolling hills, the ground is made up of rocks of some kind or other. Do you suppose that these rocks have always looked as they do today ? Are they being changed at the present time ? These are questions that will be answered in this problem.

Problem C: What are Rocks and How are they Changed ?

Question I. **Of What is our Earth Made ?**

Picture to yourself a large building. The bricks of its walls are man-made out of clay, but the stone steps and the window-sills are of granite, a natural rock. The roof is made of slate, another kind of natural rock. The grounds are surrounded by a wall built of greyish limestone which was once pale yellow when it was quarried from the earth. The trees, the soil in which they grow, the materials of the building and wall, are all solid. They are parts of our earth.

A little distance away is the sea with a harbour, gay in the summer time with yachts, large and small.

The harbour waters are part of the great liquid covering of the earth, the oceans. We cannot see the ocean of *air*, but we know that it is all around us, inside the building, filling the sails of the yachts, rippling the surface of the water.

So we see that everything on the earth is either a *solid*, a *liquid*, or a *gas*. These are the three *states* in which materials may exist.

Layers of the earth. But what is below this crust of the earth which we can see? What would we find if we could travel *through* the earth from one side to the other? Scientists have wondered, and have performed many experiments in an effort to find out. They now believe that our planet consists of a number of layers of different kinds of material, each miles thick. Each layer is lighter than the ones inside it.

The outermost layer, the atmosphere, is made of gas. Then comes the water layer, covering most of the surface of the globe. Next comes a solid crust of rock about 20 miles thick, though thinner than this under the oceans and thicker than this under the greatest mountain ranges. Beneath this lie heavier layers which, like the crustal layers, probably get hotter lower down. The layer immediately below the hard crust is believed to consist, largely at least, of that black heavy material which poured out to make the Giant's Causeway and which is to be found beneath the soil over hundreds of thousands of square miles of the earth's surface. Probably this continuous basalt layer, about 20 miles down, is always so hot that it is not far from melting, and in that condition would be capable of being forced by pressure to move about slightly beneath the solid crust. On this supposition we can readily explain earthquakes and volcanoes and the known upwards and downwards movements of land, such as the sinking of the land which once joined Ireland to the Western Isles of Scotland.

As for the central core of the earth, we know almost nothing about it and there are several rival theories as to its nature. Of one point, however, we are certain: the central portion, having a radius of about two-fifths of the earth's radius, behaves differently from the rest in the way it transmits earthquake shocks. For some of the great vibrations are not transmitted by it at all.

Life on the earth. Plants and animals live at or near the surface. Many birds fly at a height of at least a mile and some go far higher. Fish and some other animals are found in the deep sea. So you see that life on the earth is confined to a layer just a few miles thick, partly air, partly water, and partly solid earth.

SOME THINGS YOU MAY CARE TO DO

1. Try to find the folk story of Finn MacCool, an Irish giant who built a legendary causeway, i.e. a raised road paved with stones, from northern Ireland to western Scotland and crossed it to defeat a Scottish giant.

2. Make lists of substances which may be found on the earth, under three heads:

Solids	*Liquids*	*Gases*

3. Start a collection of pictures of the earth's crust, as seen in different places.

4. Read about Professor Piccard's balloon ascent into the *stratosphere*, the first ever made.

5. Try to find out about the hot belt of ozone (ozonosphere) which surrounds the stratosphere, and about the very cold belt, sometimes called the superstratosphere, beyond the ozonosphere.

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Question 2. **How are Earth Materials Changed by Heating and Cooling ?**

The story of the earth is a story of change, we have said. What have been the reasons for such changes ? Many men have wondered, and sought to find out. You, as young scientists, can learn the reasons for some of the changes by trying a few simple experiments.

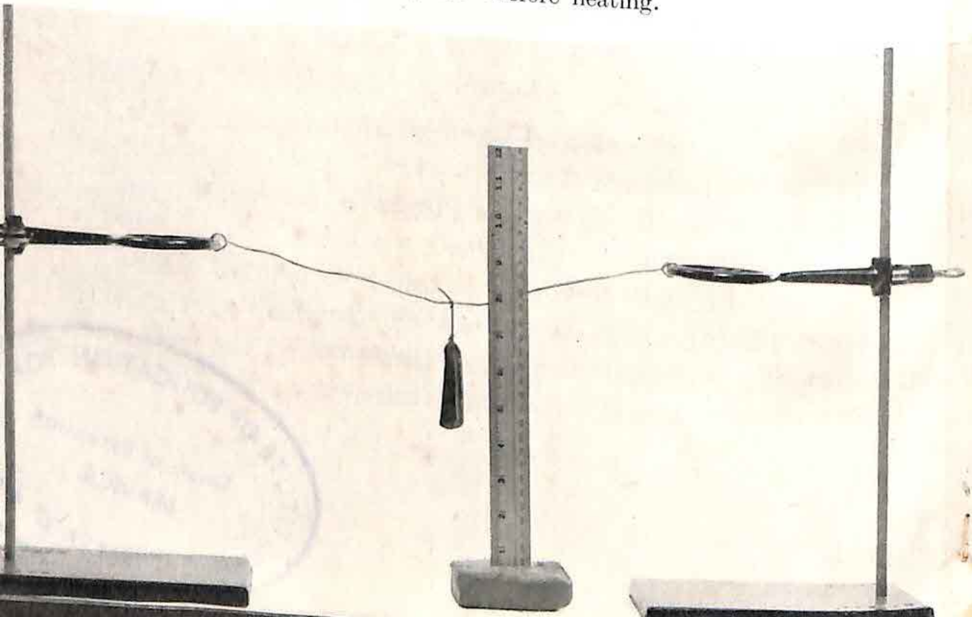
You have learned that earth materials are either solids, liquids, or gases. Let us see how each of these kinds of substances is changed when we heat it and then let it cool. The pictures in Figures 28 and 29 show an experiment with a solid—a piece of copper or iron wire. It is stretched tightly from one stand to another. A light weight hangs from its centre. Before heating the wire, measure how far the weight is from the table. After heating the wire carefully along its full length, do the same thing again.

Has heat caused the wire to lengthen or to shorten ?

Now allow the wire to cool.

How does the length of the cool wire compare with that of the hot wire ?

FIGURE 28. Before heating.



We have now found that heating a wire (a solid) makes it longer. It *expands*, we say. Figure 34 shows what happens when lengths of railway line have not been given enough room to expand.

Does water, too, expand when it is heated ? Can you remember an experiment to find out if this happens ? If not, turn back to Figure 5 on page 13. That will enable you to answer the following questions.

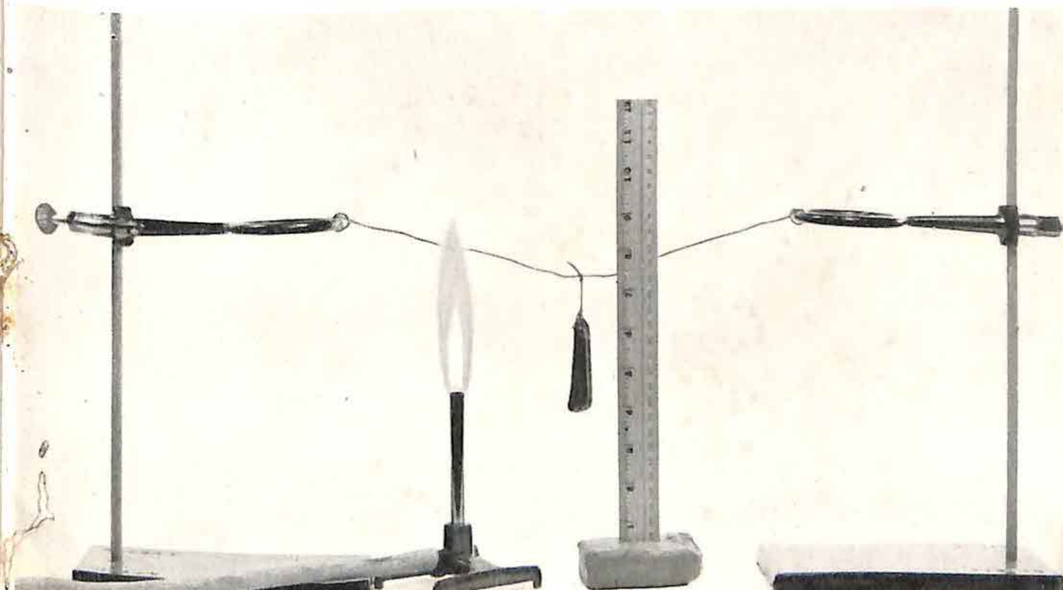
How does a liquid behave when heated ? When cooled ?

Why does the liquid in a thermometer rise on a hot day ?

Now we must make an experiment to show how a gas behaves. The gas is air. A glass tube passes through the one-hole rubber stopper as shown in Figures 30–32. Heat the air in the flask gently for a minute or two.

Does the air expand when heated ? How do you know ? When the flask is allowed to cool, what happens, and why ?

FIGURE 29. Heat causes the wire to expand. Compare the two readings on the ruler. Are the two stands the same distance apart in each picture ?



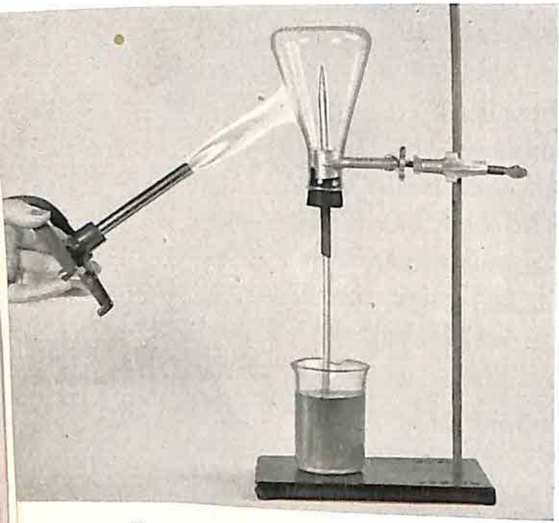


FIGURE 30. Heating air.

EXPANSION AND CONTRACTION

These two experiments and that on page 13 show that a solid, a liquid, and a gas all *expand*, or grow larger, when heated. They all *contract*, or grow smaller, when cooled. You may think that you have discovered a *principle of science*, or scientific law, but you

FIGURE 31. Why does cooling the air in the flask cause a fountain to play?

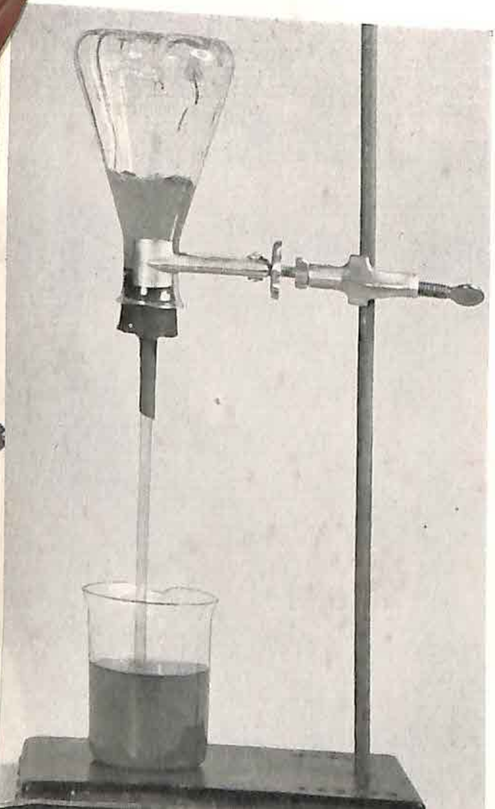
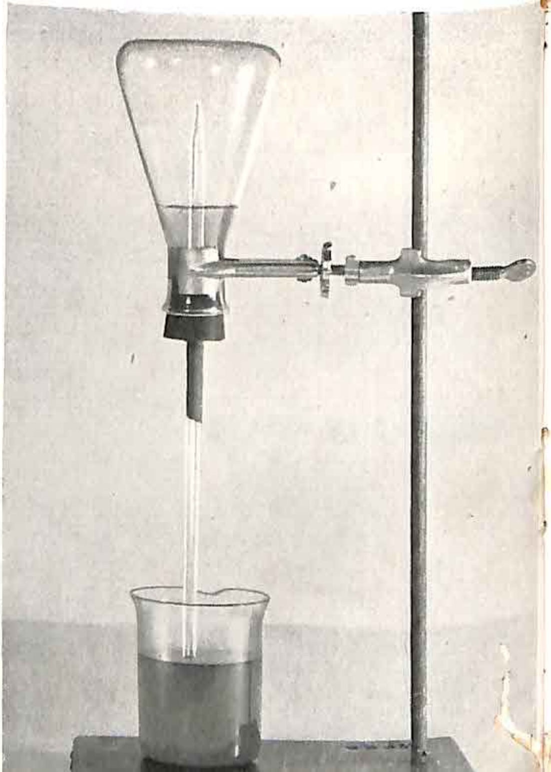


FIGURE 32. After heating and then cooling. Why is there less air in the flask than there was at first?



should not feel sure until you have experimented with other substances. Scientists have, in fact, tried many such tests and have come to the conclusion that the results show the following principle: *heating usually causes a material to expand; cooling usually causes it to contract.*

SOMETHING YOU MAY CARE TO DO

Explain the reasons for the conditions shown in Figures 33 and 34.

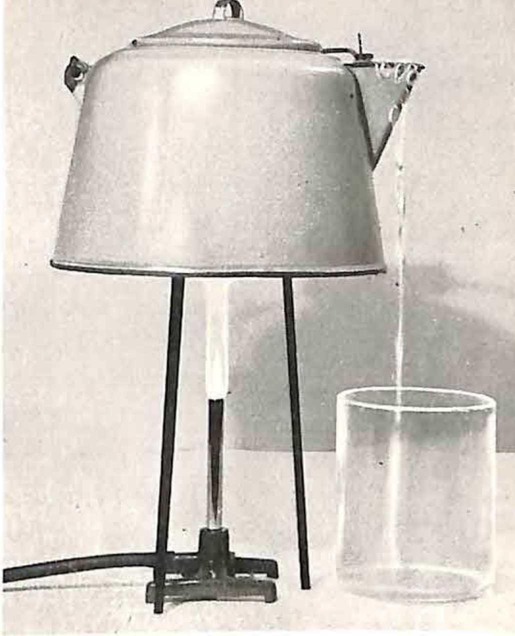


FIGURE 33. Kettle running over.

Problem C: What are Rocks and How are they Changed?

Question 3. **How are Earth Materials Changed by Great Heat and Pressure?**

You know that materials expand when heated gently. What would be the results of greater heat?

For our experiment we may use a small lump of iodine. If your teacher heats a crystal of iodine in a large test tube, a purple gas appears near the top of the tube. (See Figure 35.) When the tube is cooled some of the gas turns to liquid, and rolls down inside the tube. After more cooling, tiny crystals of solid iodine may be seen on the glass.

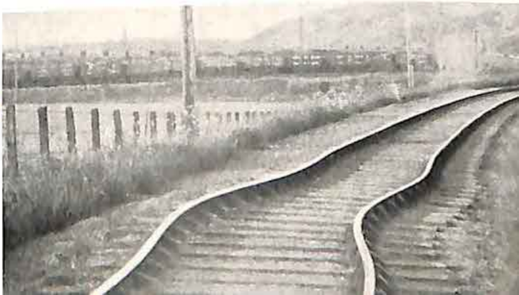
Is the purple gas the same substance as the black crystal?

In which form does the iodine occupy most space?

If heat causes iodine to

FIGURE 34. Buckled railway lines.

R. Holman



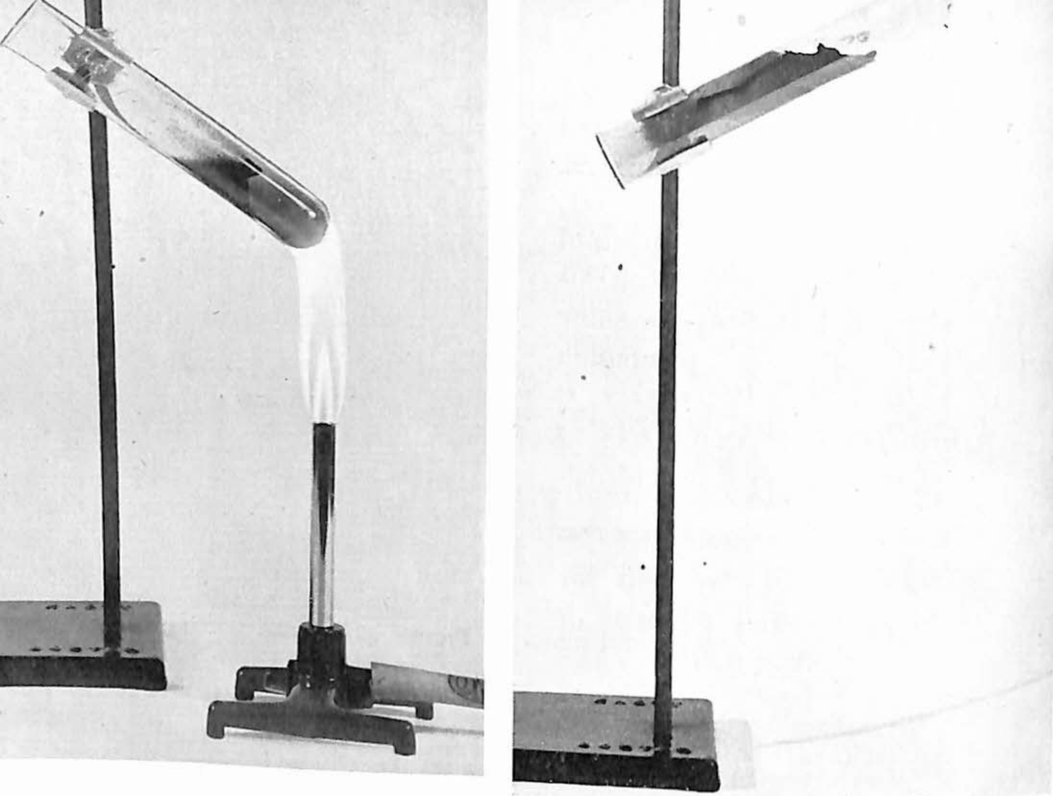


FIGURE 35. What are the three *states* in which iodine may exist ?

form a gas, would you expect that other materials of the earth might become gaseous because of heat ?

TEMPERATURE OF THE EARTH

If you go down a mine, you will find that the temperature rises as you descend into the earth's crust. The extent varies in different parts of the world, but an average figure is *a rise of one degree Fahrenheit for each fifty feet of descent.* If temperatures went on rising like this, then at a depth of a hundred miles the heat would be enough to melt all the things that make up the earth's surface. But scientists do not think that all the deep interior of the earth is liquid.

There are two possible explanations for this. The first is given by the word *pressure*.

Experiments have shown that when samples of rock are heated to melting point, and then squeezed very hard, they turn to solids again. A scientist would say they had been put under heavy pressure. Think how enormous the pressure must become as deeper layers of the earth are considered. For example, a cubic foot of soil, a part of the outermost crust, presses down with its own weight, perhaps fifty pounds. The cubic foot below it weighs at least as much and therefore presses down with its own weight added to the weight of the cubic foot above it. This continual increase of pressure goes on and the heaviest rocks beneath the surface weigh as much as one hundred and sixty pounds per cubic foot. The pressure on each square foot becomes a matter of tons not many yards below the surface. At a depth of twenty miles the pressure must be about seven thousand tons per square foot, probably enough to keep the rocks from becoming liquid despite their high temperature. In such a way we can explain the apparent rigidity of the earth.

The second explanation is to suppose that the temperature does not continue to rise all the way through the earth the deeper one goes, and this has recently been found to be the case. The radioactive substances to which the heat of the rocks is due are now believed to be confined to a thin crust of rocks not more than about twenty miles deep. If this is so the central core of the earth may not be very hot and one scientist suggests that it may not be any hotter than a wood fire. But we can only *theorize* concerning the nature of this core; perhaps man will never really *know*.

But we do know that rocks may be changed. In how many ways have you learned that this can take place?

SOME THINGS YOU MAY CARE TO DO

1. Paraffin wax is a material made from petroleum which comes from the earth. A simple experiment will show that it can change from the solid state to a liquid and then to a gas. Heat a bar of paraffin wax in a small saucepan over the stove. How soon does it change to liquid ? While heating the liquid, hold a cold glass over it, being sure that it does not touch the pan. After a few minutes let the glass cool again. Do you find a smear of solid wax on it ? How could it have got there ?

2. Show how pressure will queeze ice together. Obtain two small pieces of ice, each with a flat surface. Dry those surfaces, then press them together as hard as you can. See if you can make them stick together. Ice cubes from a refrigerator do very well for this experiment.

FIGURE 36. The Malvern Hills seen from the air.

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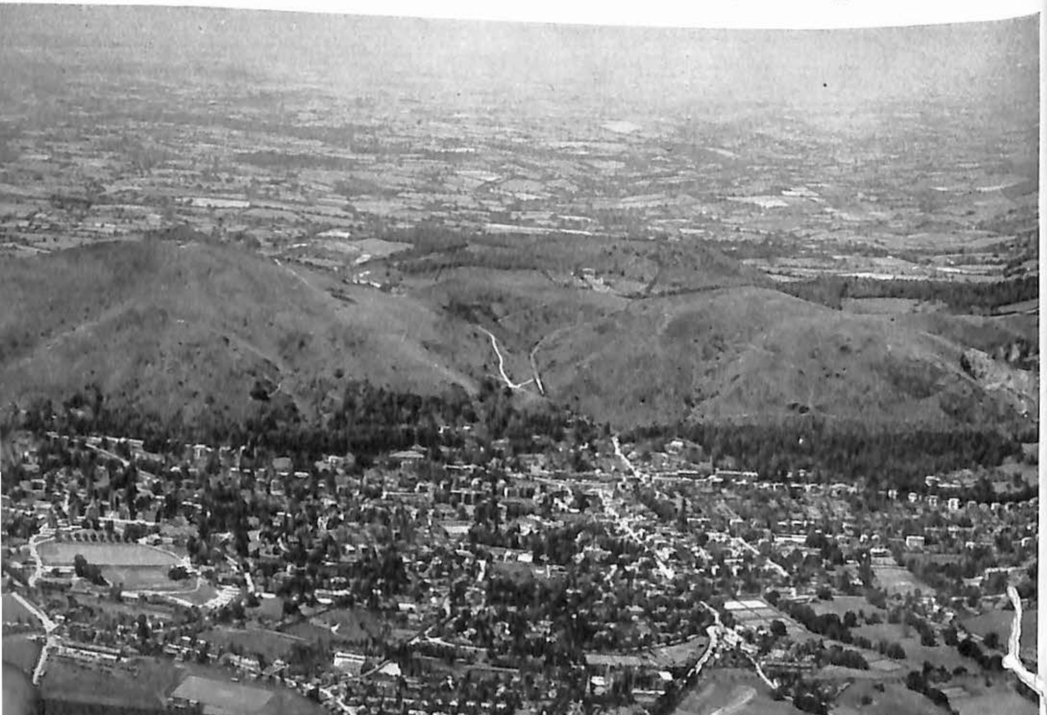


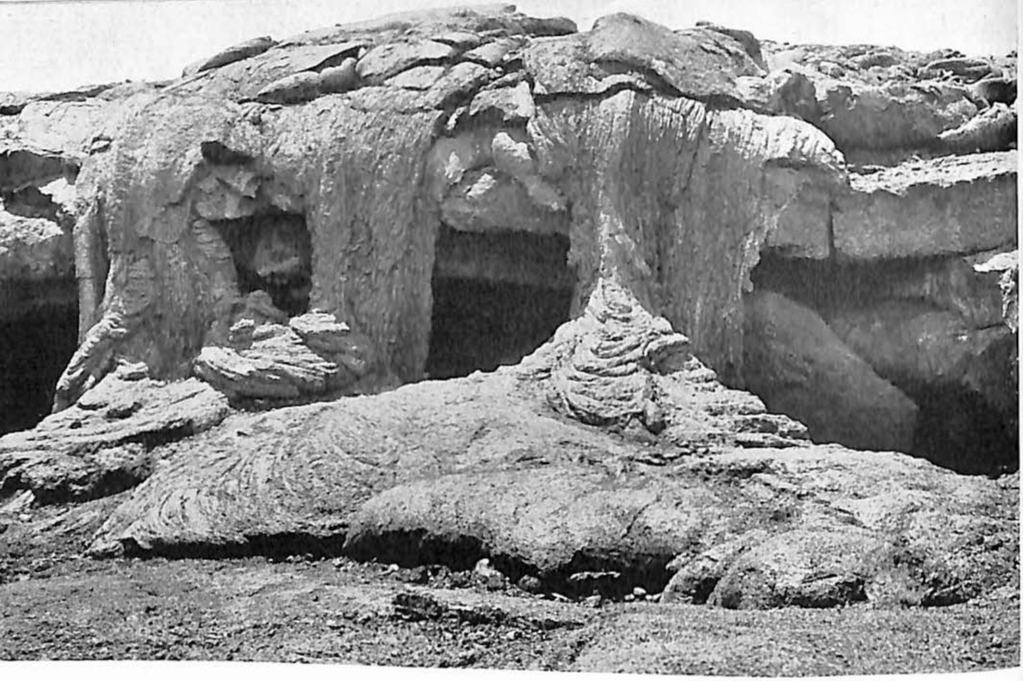
Problem D: **WHAT ARE THE DIFFERENT CLASSES OF ROCK?**

Granite, sandstone, basalt, marble, chalk, clay, slate: all of these are the names of different kinds of rock and there are scores more. To simplify matters scientists put rocks into three main groups or classes: *igneous, sedimentary,* and *metamorphic.*

The three questions that follow will give you some idea about each of these groups.

Question 1. **What do we mean by Igneous Rocks?**

Slightly west of the centre of England there rises suddenly from the rich agricultural plain a line of hard hummocky hills over a thousand feet high. Only grass, heather, and shrubs grow over most of the Malvern Hills, for there is little soil on the summits or the steep slopes. The rock is quite different from any to be found for scores of miles around: it is, in fact, mainly the core of a line of volcanoes which were active many hundreds of millions of years ago. Today this hard rock is quarried for the making of roads. It is a good example of *igneous* rock, because once upon a time it must have been the subterranean molten reservoir of the mighty volcanoes, several thousands of feet high, that belched out ashes and lava for miles around. Rocks which have been molten are called *igneous* after the Latin word *ignis* which means " flame." When igneous rocks have cooled, they are almost always very hard. When they have cooled on or near the surface of the earth, and therefore fairly quickly, one does not usually see many crystals in fragments of the rocks. In obsidian, a volcanic rock that looks like black glass, there are no crystals at all. But when, as in the



U.S. Geological Survey

FIGURE 37. This lava, now solid, was once molten.

Malvern Hills, the reservoir of molten material has cooled very very slowly, blanketed inside slopes of lava and ashes from towering volcanoes, then the rock consists entirely of crystals, all tightly wedged together and large enough to see with the naked eye.

Volcanoes. These are probably caused by semi-molten basalt from below the hard crust of the earth gradually working its way into the solid crust and, as it gets to regions of lower pressure, becoming more fluid. The main force that enables volcanoes to blow a vent

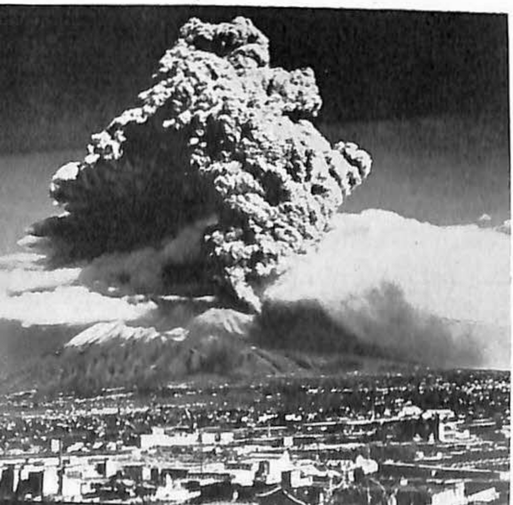


FIGURE 38. Vesuvius in eruption in 1944. This volcano in A.D. 79 completely buried the town of Pompeii under a shower of hot ashes, so swiftly that few inhabitants escaped. In another eruption in 1631 over 18,000 people lost their lives. Where is Vesuvius ?

Keystone Press Agency Ltd.

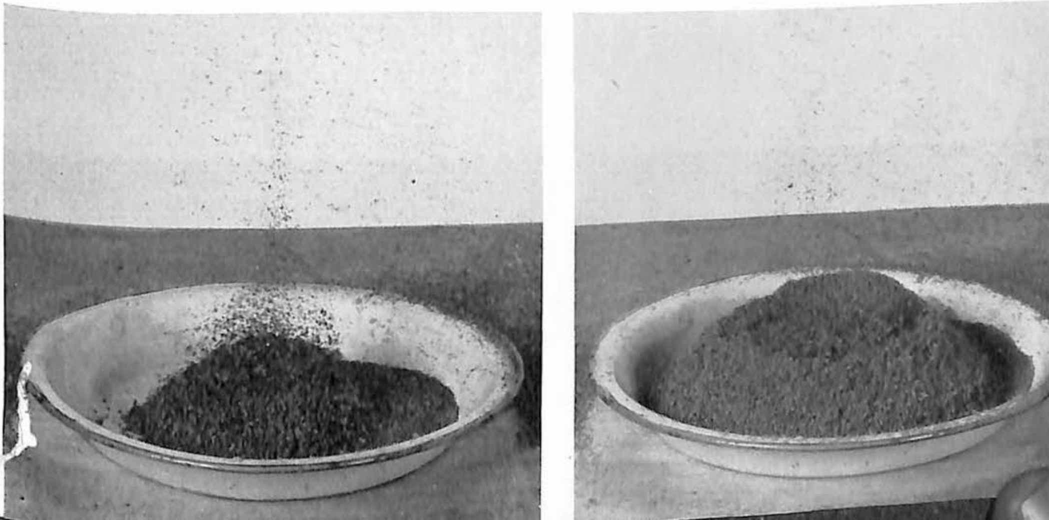
through the earth's crust is steam, and this makes up the bulk of all the gases given off by volcanoes. But deadly gases may also be present and spread destruction far and wide. Steam escaping from lava often leaves it so full of holes that the rock is light and floats upon water. It is then called pumice. But volcanic action makes various kinds of rock. Some are grey or black; others are pink, red, or brown. Granite is an igneous rock which has cooled beneath the top layers of the earth: it is usually very hard and weather-resisting.

SOME THINGS YOU MAY CARE TO DO

1. An imitation of a volcanic eruption may be produced by filling a low dish with the chemical called *ammonium dichromate*. Next drop a lighted match into the centre. As the material burns, a porous substance forms which takes up more room than the unburned material. Gas is released, pushing the substance up and forming a core, like that of a volcano. (See Figure 39.)

2. You may be interested to make your own collection of igneous rocks. If not, you can probably examine a collection in a museum.

FIGURE 39. Making an imitation of a volcanic eruption.



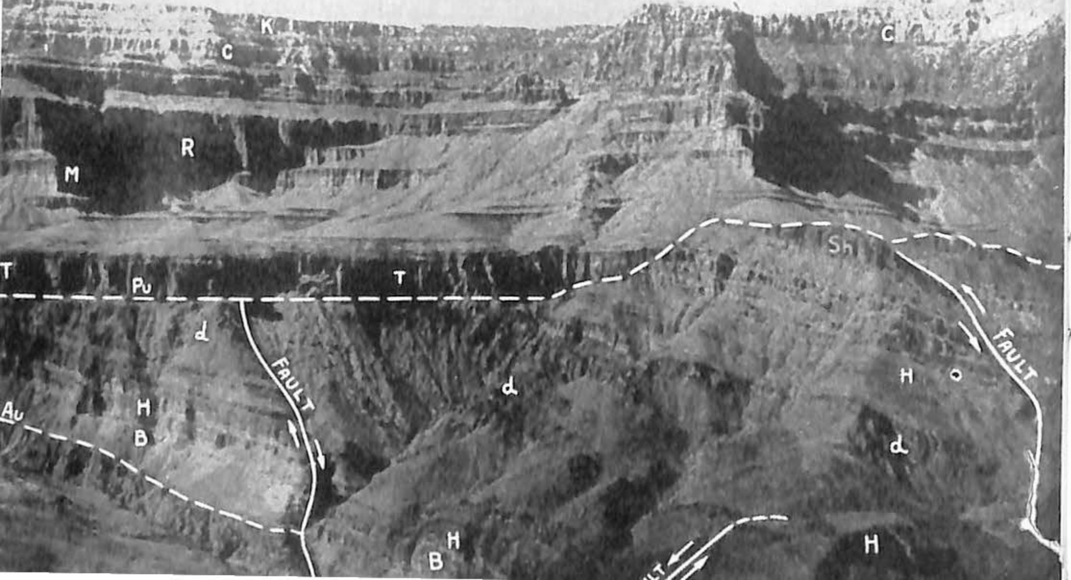
Question 2. **What are Sedimentary Rocks ?**

Fortunate people who visit the Grand Canyon of the Colorado River in Arizona in the United States are able to see that the rocky walls are layers of many different kinds of rocks ; some of them are brilliant reds and green, others white or blue. In places the rock juts out in slender towers. Elsewhere it lies in wide platforms of flat rock part of the way down the canyon sides. There are few places in the world where you could see in one glance such a mighty thickness of layers of rocks. At the bottom of the canyon is a steep, rough gorge of rock quite different from that in the sides. At the bottom of this gorge is the river. It is a roaring, rushing stream, pushing along stones, mud and sand. These are the tools with which the canyon has been cut out of solid rock.

Shale. Some of the rock layers are made of very fine material. The places marked H in Figure 40 are composed of a smooth, fine-grained rock called *shale*, which is hardened mud or clay. Most shales are dark-

FIGURE 40. The Colorado river took many thousands of years to cut this deep gorge of the Grand Canyon in Arizona, U.S.A.

U.S. Geological Survey



coloured—grey or black or bluish ; but some are red. The shale in the Grand Canyon was once fine mud on the bottom of the sea ; movements of the earth lifted it and tilted it.

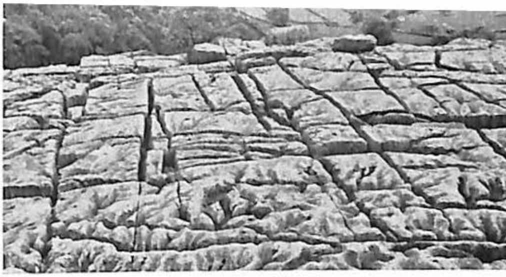


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FIGURE 41. Limestone above Malham Cove in the Pennines in Yorkshire.

Sandstone. The places marked T, K, and C in Figure 40 show layers of rock made of larger grains than the shale. They look like grains of sand, and that is what they are—sand cemented into solid rock. You need not go to the Grand Canyon to find sandstone ; it is one of the commonest kinds of rock. Most of the sand in sandstone is made of tiny bits of quartz which came from broken and worn igneous rock like granite. Many sandstones are pink, red, brown, yellow, or even green because there is iron in the cement which holds the bits of sand together.

Limestone. One of the common kinds of rock is known as limestone, because when heated with coke in kilns it is converted into lime. What are the uses of lime ? The places marked B, M, and R in Figure 40 are of limestone. This rock has been formed from the shells of sea animals cemented together with lime salts from the sea water. Layers of such material gradually become hardened into solid rock. Some of them have been lifted above the sea by earth movements, and now are

FIGURE 42. Chalk cliffs of the English Channel at Beachy Head.

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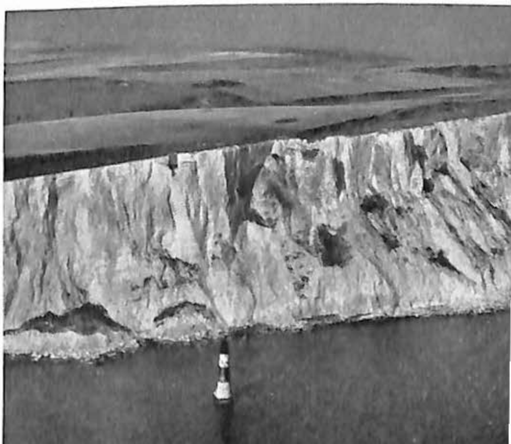

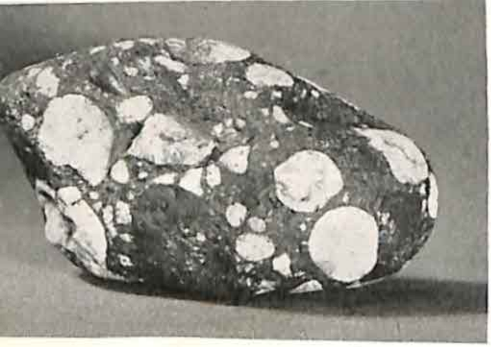

Carson Brevoort

FIGURE 43. A worn fragment of the rock conglomerate called pudding-stone.

part of the land. England has a number of limestones which are valuable building stones: examples are Bath Stone and the grey limestone of the Pennines such as you can see in Figure 41.

Chalk (Figure 42) is a very special form of limestone which must have been formed in a very clear sea. The hard bands of flint in the chalk have largely been formed of remains of sponges.

Conglomerate. Some rocks look as if they were made of many pebbles, large and small, cemented into a solid mass. They remind us of raisins or plums in a pudding. In fact, such rocks are sometimes called *pudding-stone.* Another name for them is *conglomerate* because they are a conglomeration, or mixture, of different kinds of rocks and minerals, as you can see in Figure 43.

Sedimentary rocks. Shales, sandstones, limestones, and conglomerates all belong to a large group of rocks called *sedimentary rocks.* Perhaps the most striking thing about them is that they lie in layers. (See Figure 44.) A *sediment* is something that settles, in water or in air. Most sedimentary rocks were formed under water, but some were formed by layers of dust which settled out of the air.

Most sediments, when they settled, were at first loose layers of sand and mud and shells. Now they are solid rock. What changed them? One cause of their hardness is pressure. It has been reckoned that the pressure on a square foot of rock a mile below the surface is

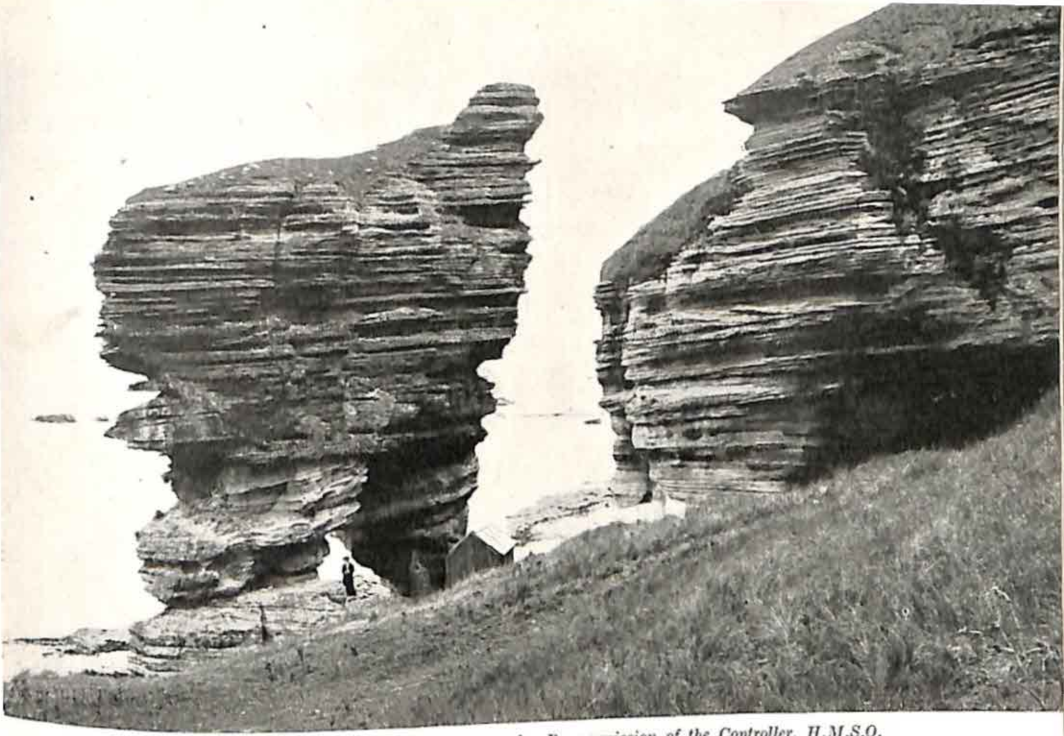

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FIGURE 44. A cliff at Covesea, near Elgin, made up of layers of sandstone. Can you tell the height of the stack ?

more than three hundred tons ! No wonder that under such weight the mud is squeezed into solid shale and the sand into sandstone !

The particles of most sedimentary rocks are also held together by a kind of cement which comes from substances dissolved in the water that has seeped through the earth's crust. Two common cements are carbonates of calcium and iron. Dissolved carbonate of calcium is the chief cause of "*hardness*" of water and is deposited as "*fur*" inside the kettle.

In caves at Clermont-Ferrand in France the water contains so much dissolved carbonate of calcium that when it trickles slowly for a few days over objects it completely coats them with hard calcium carbonate and the objects are sold as "petrified." Birds' nests and small baskets of strawberries are "petrified" in this way. What does the word *petrify* really mean ?

SOME THINGS YOU MAY CARE TO DO

1. Have ready a glass jar of water. In a dish mix sand, pebbles, small shells, and fine clay or dust. Pour the mixture into the water and let it settle. *Does it settle in layers?*

2. Make or study a collection of sedimentary rocks.

3. Good soil usually contains lime in the form of calcium carbonate. This has come from lime which has been added or from crumbled limestone. An easy test is to dig about four inches down into the soil and get a tablespoonful of this below-the-surface material. Place it in a glass of water, and add about a teaspoonful of hydrochloric acid, which you can get from a chemist's shop. If the mixture bubbles, the soil contains lime. If it does not bubble, it probably needs lime in order to produce good crops.

4. Show that sandstone is porous. Weigh a dry piece, then let it soak in water overnight. Weigh it again after you have wiped off any loose water on the surface. Does it weigh more? Repeat the same experiment with a piece of dry brick.

Problem D: What are the different Classes of Rock?

Question 3. **What do we mean by Metamorphic Rocks?**

Fifty years ago most children learned to write on slates. Blackboards used to be made of slate. Slate is a hard rock which can be split into very thin layers. These can then be sawn into pieces of the required size which do not easily break and which resist the action of wind and rain. That is why they have often been used for the roofs of houses. How was this useful rock formed?

Slate is only to be found in regions where the rocks have been very much bent and pushed about. We can

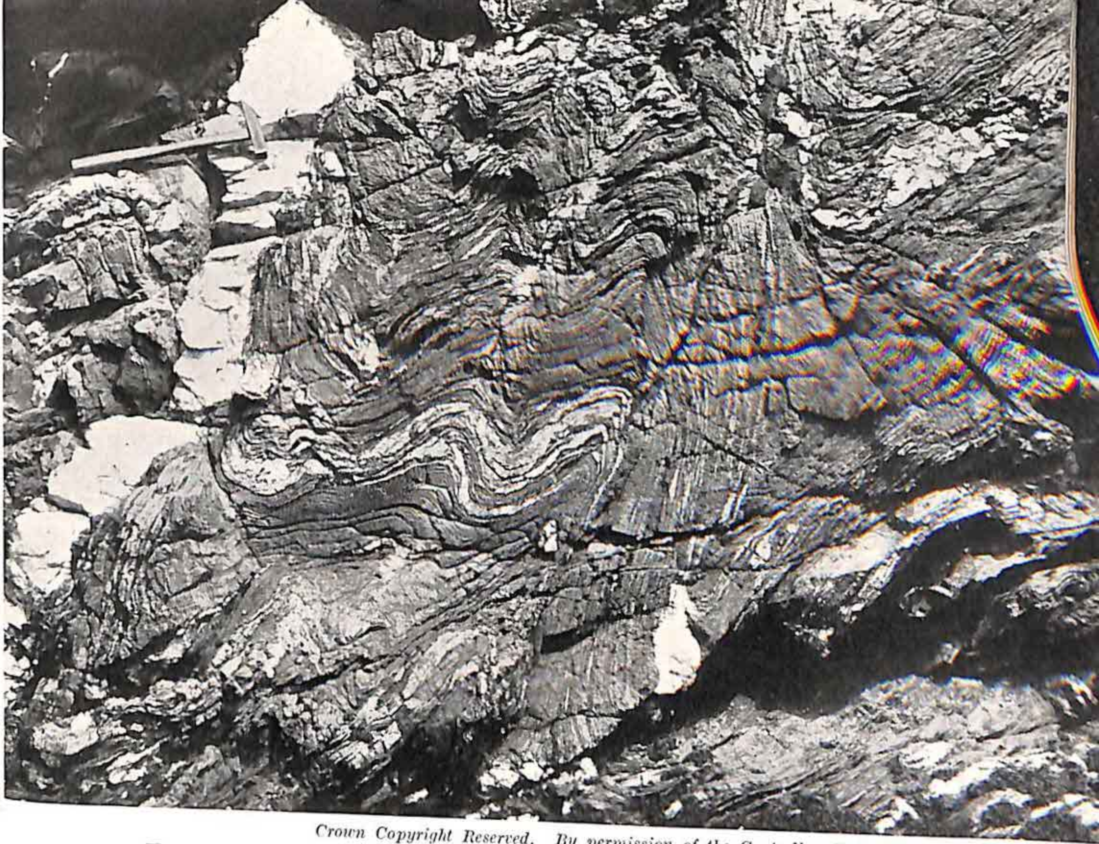

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FIGURE 45. This is very contorted *gneiss* in Kincardineshire, Scotland. The hammer rests on a vein of quartz.

always see when this has happened, for layers of such rock are generally not parallel, as in sedimentary rocks, but lie at varying angles, and with cracks and other signs of movement and even of confusion among the layers. Figure 45 shows how such rocks often appear when seen close up.

Slates also tell their own story, for sometimes they contain fossils which clearly have been pushed out of shape. Since these fossils are those of animals that lived on the sea bottom, we know that slates have been formed from fine sediments which have been thrown into folds and pressed out of their original layers. Probably this process was accompanied by heat and this would help to explain their hardness and the fact

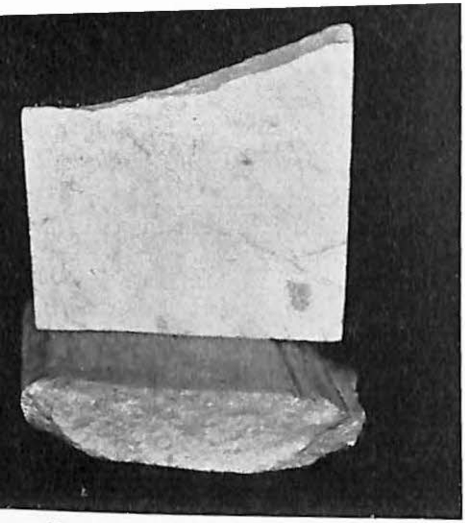

FIGURE 46. When limestone is changed and hardened, it becomes a marble. Any rock that can be polished may be called a marble.

that fossil remains in slates are comparatively few.

Such rocks, the original structure of which has been changed, are called *metamorphic rocks* from a Greek word meaning "change of shape."

Metamorphic rocks which show a parallel banding, mainly of crystals of quartz and mica, are usually known as *gneiss*. Gneiss is almost as hard as granite which it resembles to some extent.

Other contorted rocks, not always as hard as gneiss, and sometimes consisting predominantly of one mineral, are known as *schists*. The minerals found in such rocks are often very special ones, such as that from which asbestos is made.

White Carrara marble, which comes from Italy, is another metamorphic rock. No doubt it was originally a very pure limestone which was exposed to heat and pressure below other layers of rocks.

What three classes of rocks have you studied? What are some examples of each?

SOME THINGS YOU MAY CARE TO DO

1. Make or study a collection of metamorphic rocks.
2. Limestone and forms of marble derived from limestone may be told from other kinds of rock by dropping acid on them. If you use any kind of acid (vinegar, lemon juice, or hydrochloric acid), bubbles of carbon dioxide are given off.

Problem E: **WHAT ARE OTHER WAYS IN WHICH THE EARTH HAS BEEN CHANGED?**

Having learned about the changing materials of our earth, let us now turn our attention to other changes, both past and present. Some of these have to do with living things, and others with the soil, and with climate.

Problem E: What are other Ways in which the Earth has been Changed?

Question 1. **What do Fossils teach us about Changes in our Earth?**

Look at Figure 47. This remarkable photograph from a park in Glasgow shows tree trunks and roots made of rock! They are bedded in shales which belong to the Carboniferous series of rocks, that is to the rocks in which most of the important coal seams are found. The broken-off trunks belong to the type

FIGURE 47. The Fossil Grove in Glasgow.

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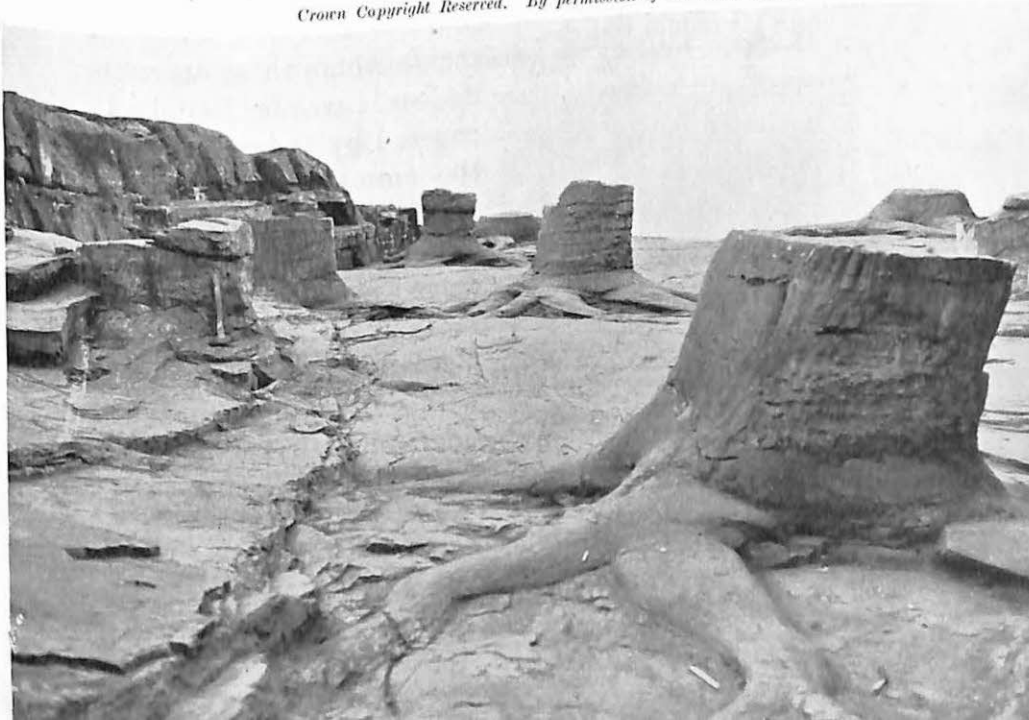


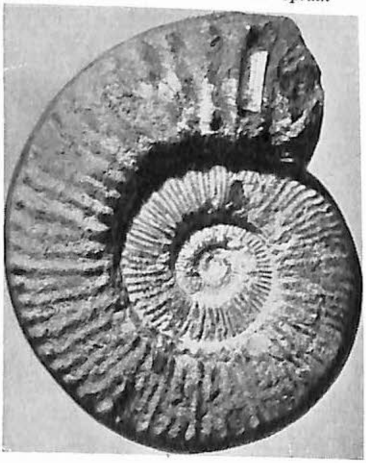
of tree known as " Scaly Tree " which flourished greatly in the Carboniferous period ; no trees of this type have existed for scores of millions of years. These trees grew in swamps ; perhaps the main part of the trunk rotted away above water level, leaving only the roots and base of the trunk to be buried by sand and leave in time the mould or cast of their shape on the rocks.

Fossils. Do you know what we mean by fossils ? They are the " casts " or impressions or petrified remains of plants and animals that lived in past ages, buried and preserved in rocks. The name is derived from a Latin word and means " something dug up."

Have you ever seen a fossil similar to the ammonite shown in Figure 48 ? Casts like this are to be found near Oxford, right in the very centre of England, at the furthest distance from the coast. Yet they represent the internal casts of sea animals. How did they come to lie in their millions in the very middle of the land ?

FIGURE 48. An ammonite. This photo is one-fifth real size.

Dr. Sprath



We believe that scores of millions of years ago the region where these ammonite fossils are now found was covered by the sea. When the ammonites died, their shells, which hitherto had largely been filled with air, ceased to float and sank to the bottom of the sea. Here they became filled with the mud and fine shell fragments that collect on the bed of the sea. At a later period the layers of sediment in which the shells had been buried were raised above sea level, and became rock. Though in the course of this vast period of time the actual shells have been dissolved away, yet the hard cast remains and shows us the shape of the original shell.

How fossils are formed. Very few of the animals and plants that die today will form fossils for future ages. In general the bodies both of animals and plants decay and nothing remains. For instance, have you not sometimes seen a dead fish floating on the surface of a river or lake ? It gradually becomes putrid and falls to pieces. It will not form a fossil.

In Figure 49 you see fish which have been killed by an unusual high tide and storm that carried the sea water for a short while over the land. If those dead fish lying on the mud were quickly to be covered by blown sand, they might ultimately form fossils, like the fish in Figure 50.

So you see that special conditions are necessary for the making of fossils. *In general the remains of the living animal must somehow be buried and preserved from normal rapid decay.* Hard shells and bones that are quickly covered by sand or mud either on dry land or in water are preserved best.

FIGURE 49. Fresh water fish killed by salt from an unusually high tide which swamped freshwater pools inland.
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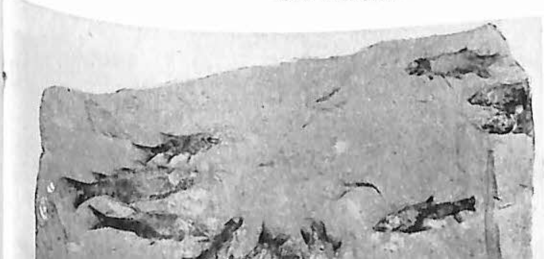
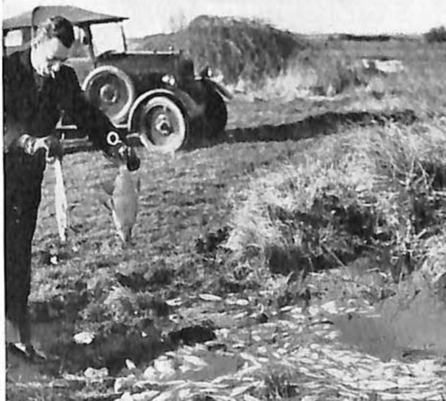
FIGURE 50. Fish casts in rock.
Real Photographs Co. Ltd.





In very cold regions remains of animals that have fallen into mud may be preserved complete for tens of thousands of years. This happened in Siberia where bodies of the great woolly elephant have been found frozen in the soil. In warmer regions, where natural tar and asphalt are found, the bones of tigers, wolves and giant sloths have been found in tar pits.

There is still another way in which living things may be buried, and turn to rock. They may be covered by drifting sand in a dry region. That is how the dinosaur eggs found in the deserts of Mongolia were preserved. (See Figure 51.) Most dinosaurs were huge animals: their name means "terrible lizard."

From this story, and from similar stories to be read in other rocks, we can draw two conclusions. This earth of ours is very, very old, and has gone through many, many changes.

SOME THINGS YOU MAY CARE TO DO

1. You may make an impression of a fossil in the following way: press a shell or a piece of fern between two layers of clay or plasticine. When you separate the layers, the shell or fern lies on one, and the mark it made on the other shows its shape. (See Figure 52.)

2. Make a plaster cast of one side of the shell by putting wet plaster of Paris into the impression made in clay by a shell.

3. Examine a fossil (or a picture of one), and write a story which tells how it may have been preserved.

FIGURE 51. A nest of six dinosaur eggs turned into fossils. These eggs are at least eight inches long.

American Museum of Natural History

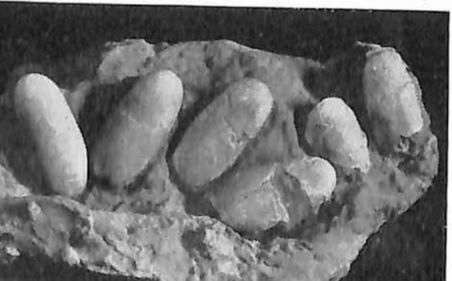
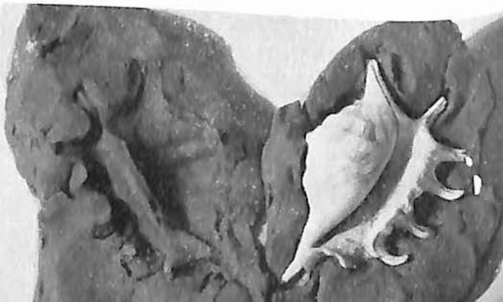


FIGURE 52. Making an artificial fossil.



Question 2. **How do Weather and Wind Change the Earth's Surface ?**

You have already learned, from the story of marine fossils, that the earth has been raised and lowered in various places. One important thing to remember is that even while land is being raised, it is also being worn down.

Look at Figure 53. This shows how layers of sand which were once laid down by a glacier are being washed away by the direct action of rain. On the tops of the sand pillars on the right little patches of soil show the level at which vegetation once grew. Not a great time ago the vegetation was continuous with the grass on the surface in the background of the picture. Between the foreground and the background runs a little stream which has carried away the vast quantities of sand washed down to it by the rain.

Weathering. It is easy to find evidence of changes brought about by weather. If you can find a cliff or quarry in your neighbourhood, it will probably have a mass of loose stones piled against its foot. You may find little patches of soil among the stones and perhaps grass and weeds growing there. If you compare the loose stones with those of the cliff, you will find that many of them are the same. The solid rocks have become broken and have fallen down because of *weathering.*

This word weathering means the splitting-up and decomposition of rock by heat and cold helped by water, frost and ice, and by the gases of the air.

FIGURE 53. Sandstone washed away by rain in Scotland.
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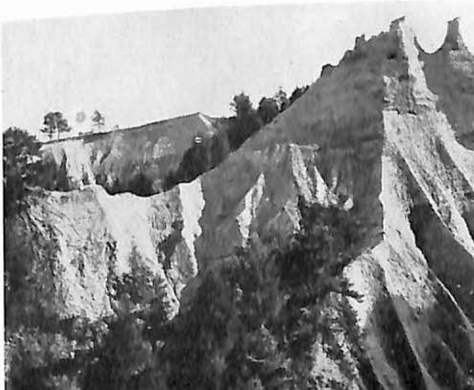

When a rock weathers, the surface is gradually broken. Water gets into tiny cracks and freezes.

How does this ice formation widen the cracks?

Changes of temperature cause the rock to expand and contract. Oxygen, carbon dioxide and water also attack rocks. Water, for example, may dissolve the elements that hold rocks together. The loose material which results from weathering is still rock. It is a solid; that is, it is neither gas nor liquid. Much of it becomes a part of the soil in time.

Once rocks begin to break up, the fragments may be carried away, perhaps by glaciers but more commonly by rain, streams and rivers. At the coast the waves usually carry away a lot of sand. Frequently, too, they have made the sand: can you guess how?

Very small particles or rock get blown away by the wind. You may not think of wind as a force which wears away the land. But have you ever seen a stone building being cleaned by a blast of sand? The surface, which was black and discoloured, is worn off by the sand blast, and comes out bright and clean. In a similar way sand blown by the wind wears away rocks.

FIGURE 54. Rocking stones in Yorkshire cut to strange shapes by wind-blown sand. How can you tell that these are sedimentary rocks?

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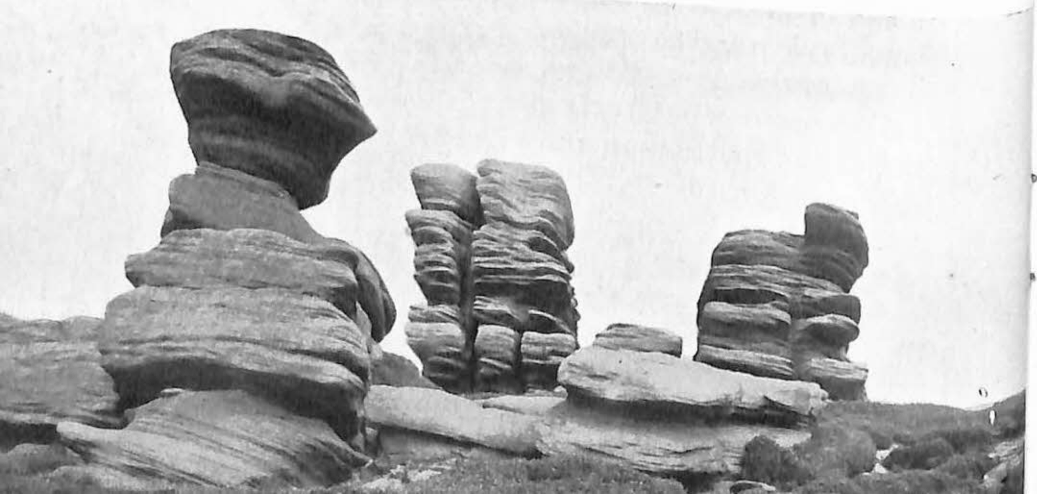

Have you ever seen such curious formations as those shown in Figure 54 ? They have partly been formed by sand blown in the wind. Soft rock has been cut away faster than have the harder materials.

The soil, sand and dust caught up by the wind may blow hundreds of miles before dropping to the ground. Or it may move only a short distance. Sand dunes along the shore of seas and lakes may change their position from year to year; look at Figure 55. The wind is responsible for such a change. But it does not pick up a whole sand dune and set it down somewhere else. No, it moves the dune one grain at a time. The sand grains blow up one side of a dune, and drop on the other side. Winds that blow from the same direction day after day can cause a dune to change its position in a fairly short time.

We may conclude that changes are still going on, as they have for thousands and millions of years, and that wind and weather have been in the past and still are two of the important causes of these changes.

FIGURE 55. These fir trees, the tops of which are still living, are being gradually buried by the drifting sand in Elgin in Scotland.

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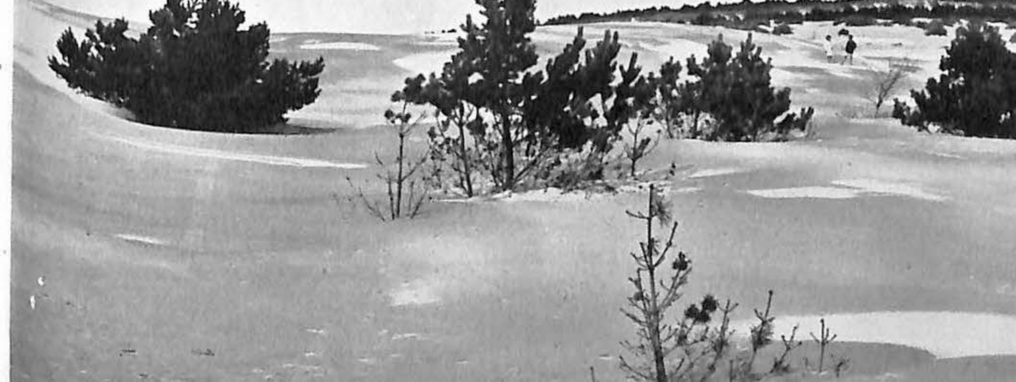


SOME THINGS YOU MAY CARE TO DO

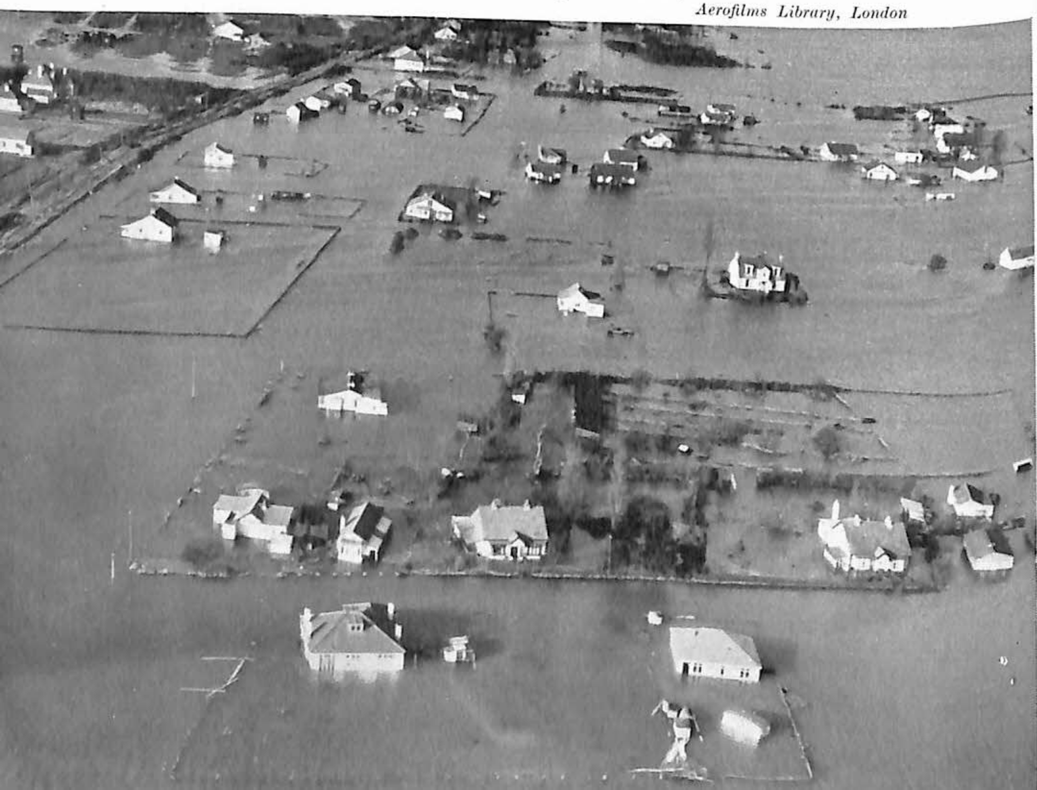
1. This experiment may show you one of the reasons why rock crumbles. Hold small pieces of different kinds of rock, by means of tongs, in the hot flame of a gas burner. Then plunge them quickly into water. Do any of them crack and break ?

2. When you have a period of very cold frosty weather soak a small lump of chalk or limestone in water for some hours, and then put it out of doors for a day or two. Examine it carefully when the frosts are over. What has happened ?

3. Show how wind can move sand dunes. Build a landscape in a large tray, using sand, small branches of evergreen to represent trees, and a toy house or two. Place an electric fan at one end of the tray and switch on the current. Watch the action of the sand.

FIGURE 56. High winds and high tides flooded the East Coast of England overnight in 1953.

Aerofilms Library, London



Question 3. **How does Water Change the Earth ?**

You know that much water may fall in a single heavy rain. In some places there is very little rainfall in a year, but in other places as much as a foot may fall in a day.

What becomes of rainwater ? To answer the question, you need only watch a field or the roadside after rain. Three things happen. Part of the water evaporates into the air. You know how soon pavements become dry in summer. Some water sinks into the ground. There it dissolves minerals and so is able to furnish food to plants. Or it seeps through crevices and pores far down into the solid rock. The rest of the water runs off across the surface, gathering into streams that flow downward until they enter lakes or rivers or the sea.

You may show that limestone is slightly soluble in water by stirring some powdered chalk (one form of limestone) in it for several minutes. Filter the liquid. If some chalk has dissolved, the water that comes through the filter paper will be " hard." It will not form good suds when soap is added. Compare it in this respect with tap water and boiled water.

How does this experiment show one way in which water changes the earth ?

HOW WATER WORKS

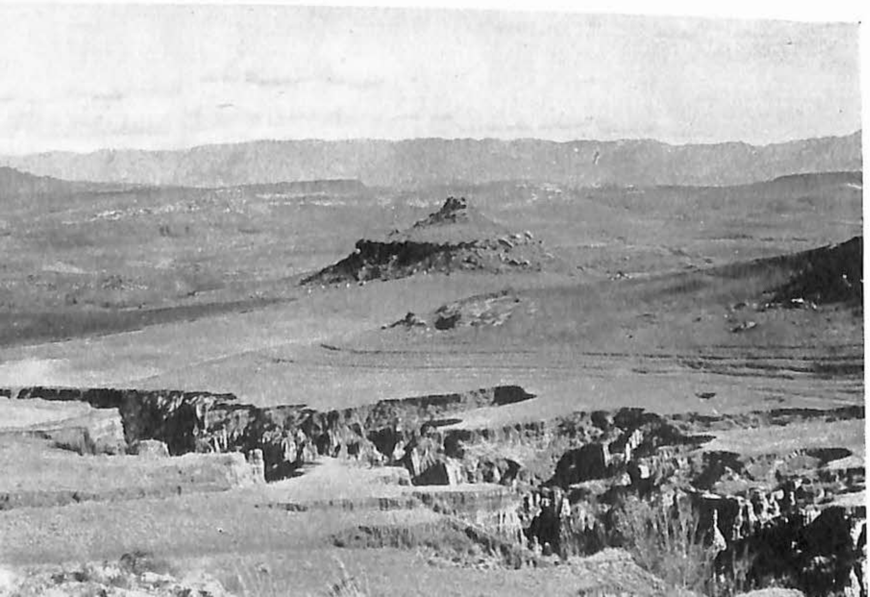
Sometimes men make water do work for them, but more often it does its own kind of work, changing streams, hills, and valleys. It wears rocks in the beds of the streams, loosens them from the banks and uses the rocks as its tools. Even clear, gently flowing streams carry tiny particles of sand. Swift streams move stones, and even huge boulders.

Figure 56 shows the effect of the sea being forced inland by the combination of high tides and high winds. Rivers in flood can be equally destructive.

The course of a stream. Water starts to work even before it gathers into streams. On a flat smooth surface it picks up small particles and moves them along. Where there are weak places, such as cracks in clay soil, the water may start a gully. In regions where a lot of rain falls in a short time farmers know all too well how fast gullies grow and destroy their fields.

Suppose we follow a little stream from its source, on a high plain. Where it begins its journey, the slope may be steep and the speed of the water great. The stream is soon joined by others to form a larger stream and finally a river. As the river flows on its way, it moves more slowly. Here the valley is wider and sloping. Because the current is not so fast, it cannot carry heavy pieces of material. Wherever the river makes a bend, it hurls its load of sand and clay against the outer bank. The result is that at such a point the bank is cut away, while on the opposite side of the

FIGURE 57. Soil erosion in South Africa. The gully you can see in the foreground is deepened by every rainstorm. *S. P. Jackson*



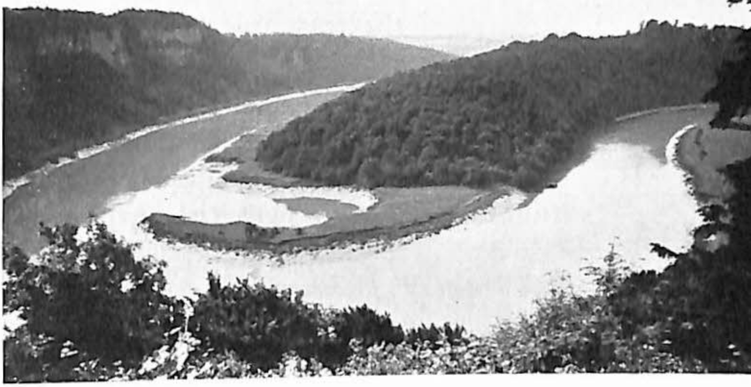


FIGURE 58. A meander in the river Wye in Gloucestershire. Can you see the steep bluffs being undercut on one side, and the deposits being dropped on the other side ?

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river some sand and clay is deposited. Perhaps you have noticed this yourself ? It can be seen in quite small streams and rivulets.

The lower part of our river course may wind its way through a nearly level plain. Here the current is slow, because the water has nearly reached the level of the sea or the lake into which it empties. The sediments settle, forming an alluvial plain.

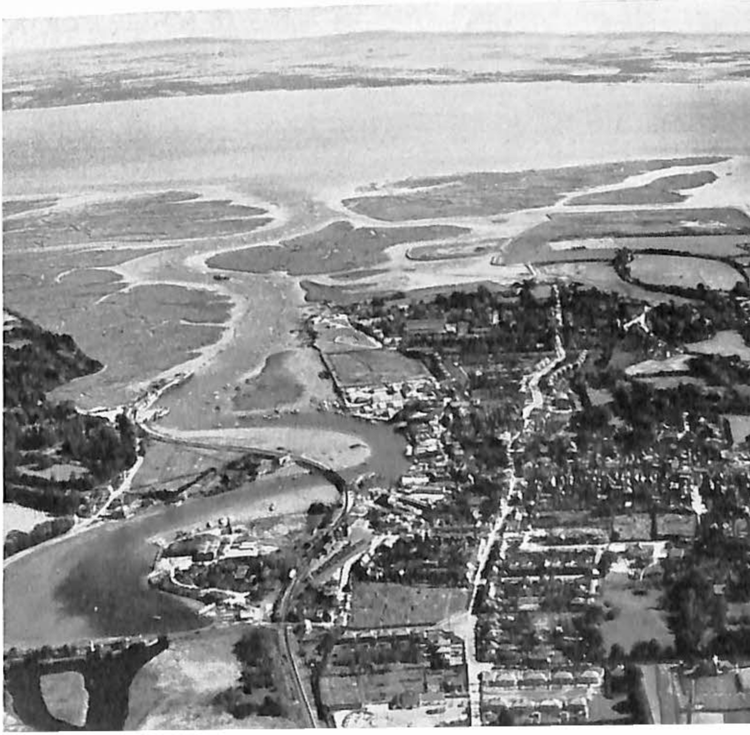

FIGURE 59. The river at Lymington is dropping sediment in the shallow sea between Hampshire and the Isle of Wight. Is the river meandering ?

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Some of the rock fragments carried by streams are finally deposited along the courses of broad rivers. Other materials are carried on into the sea. Both of these things are important to us, as you will learn in later studies. For the moment it is enough to see that running water changes the surface of the earth.

SOME THINGS YOU MAY CARE TO DO

1. After any rain you may watch how the water wears away the land and builds it up in other places. If possible, make a sketch to show the change in one small place, such as the bank of a very tiny stream.
2. Make a scrap-book of pictures showing how deserts are irrigated in various parts of the world.
3. Make an illustrated book about the river nearest to your school. Describe its course from its source to where it flows into the sea.

Problem E: What are other Ways in which the Earth has been Changed ?

Question 4. **How does Ice Change the Earth ?**

Every year, if you live where winters are cold, you can see changes brought about by the action of ice. For example, nearly every spring the roads must be repaired. Why does the winter's ice and snow have such an effect ? An experiment may help you to understand.

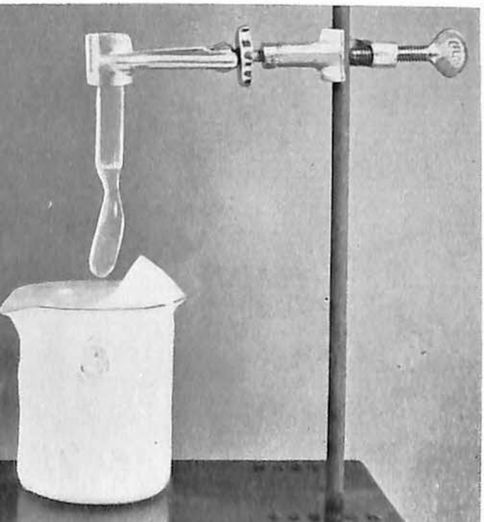


FIGURE 60. Why does the glass break ?

If your teacher carefully heats a small test tube, he can draw it out so that there is a narrow part near the middle. If he then puts some water in the bottom part of the tube (up to the middle) and places the tube in broken ice and salt (or broken ice and methylated spirit), it will not be long before you hear the snap of breaking glass.

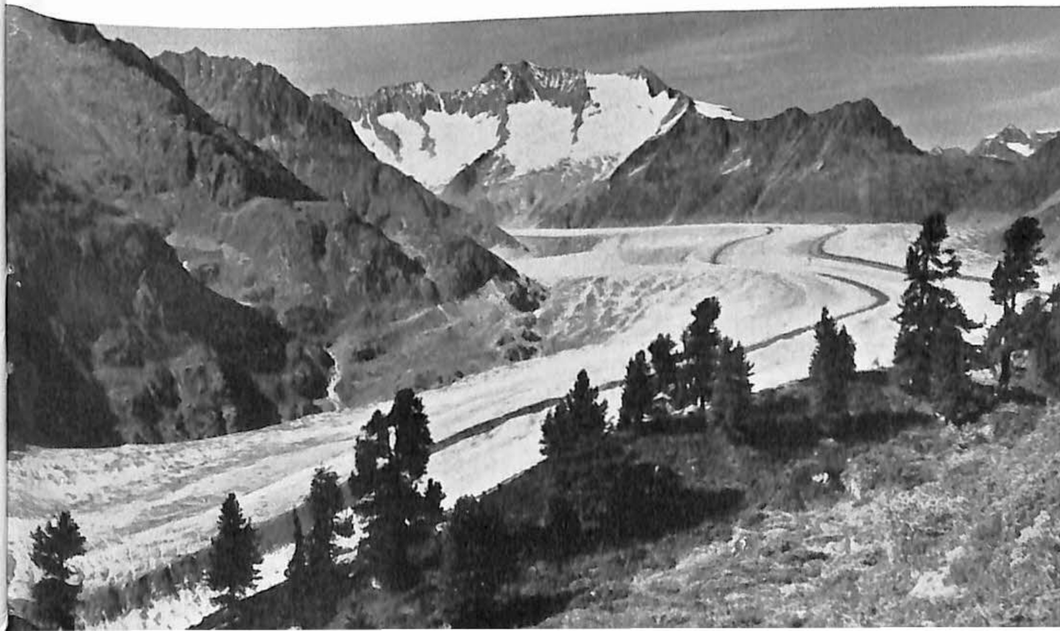
This experiment shows the action of ice on glass, but will ice cause solid rock to break? Perhaps you have already experimented with chalk (see page 66). If a piece of sandstone is soaked in water overnight and then frozen, what happens to the water in the pores of the rock? After a while you might rub the rock to see if any little pieces crack off.

GLACIERS

Freezing and thawing tend to break up rocks to produce materials that go into soils. But ice has had yet another effect upon the soils of many parts of the world. In any region where more snow falls in winter than can melt away the next summer, there are *glaciers*.

FIGURE 61. A glacier in Switzerland. The two dark lines are stones that mark the junction of tributary glaciers.

Alb. Steiner, St. Moritz

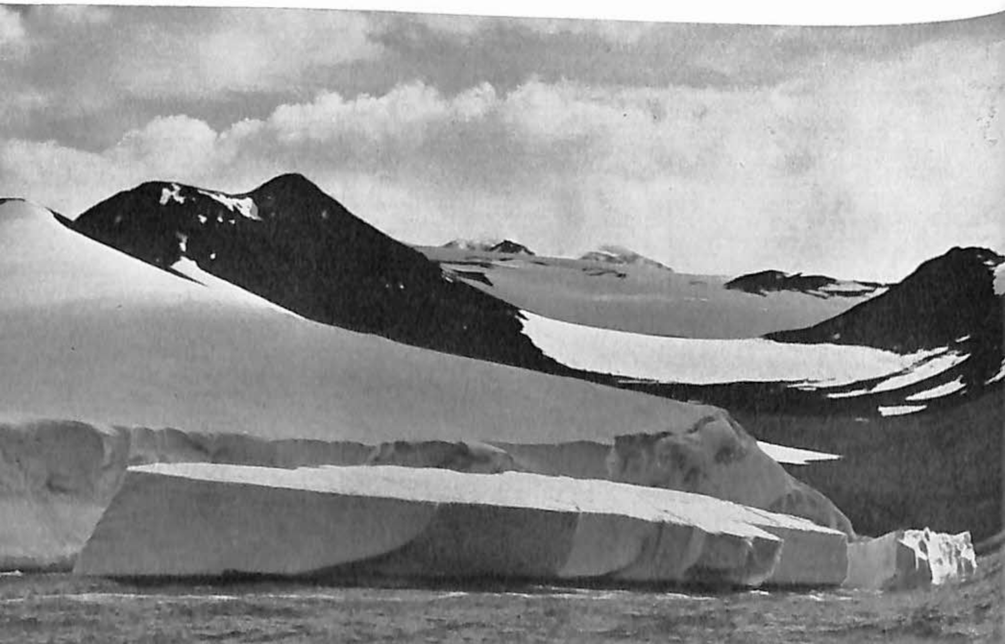


A glacier is simply the snow of many years, hardened into ice. In mountainous regions the snow gathers in deep valleys, forming mountain glaciers like the one shown in Figure 61. They are sometimes called "rivers of ice," and, like rivers, they move down the valleys. Their motion, however, is slow, being usually not more than one or two feet a day.

Glaciers and icebergs. Sometimes a glacier reaches the sea, where its edge may break off, forming icebergs like that shown in Figure 62. This photograph was taken in the Antarctic. In certain cases, the glacier pushes forward into the water for quite a distance before the end breaks and rises to the surface. Icebergs formed in this way may be enormous. When ice floats, most of its bulk is below the water surface. An iceberg which towers ninety feet above the water may reach nine hundred feet down. Any ship that

FIGURE 62. This iceberg has just broken off from a glacier in Antarctica.

Paul Popper Ltd.



collides with such an iceberg is damaged as much as if it had run head on into an island of solid rock.

Glaciers and soils. In spite of its slow motion, a glacier wears away great quantities of rock. Rock fragments carried by the glacier are ground against rocks over which the ice travels. As the glacier moves, its collection of rock fragments acts like a huge file or rasp. The bedrock is scraped away, and the broken pieces are added to the material carried by the glacier.

When the ice of a glacier melts, any material that it carries is dropped. This consists of small sand grains, clay, pebbles, stones and boulders. These things are not sorted out as they would have been by water.

Over large areas of northern Europe and of North America we find that the top layer of rock is just this sort of mixture, and we believe it was spread by glaciers. In England the things left by the ice are mainly gravels and that mixture of stones and ground rock dust which we know as "*till*" or "*boulder clay*." It is not a real clay at all and has none of the properties of a true clay. But it makes fertile agricultural soil, especially where decayed plant remains have accumulated for a long time on the surface.

SOME THINGS YOU MAY CARE TO DO

1. Float an ice cube in a glass of water. Estimate what part of it extends above the water surface.

2. Make a scrap-book of pictures dealing with all kinds of ice, from that of icebergs to that produced by giant refrigerators.

3. Read more about glaciers in an encyclopedia and try to find out (*a*) how men proved that glaciers move, (*b*) how we can recognize mountain regions and valleys that were formerly occupied by glaciers.

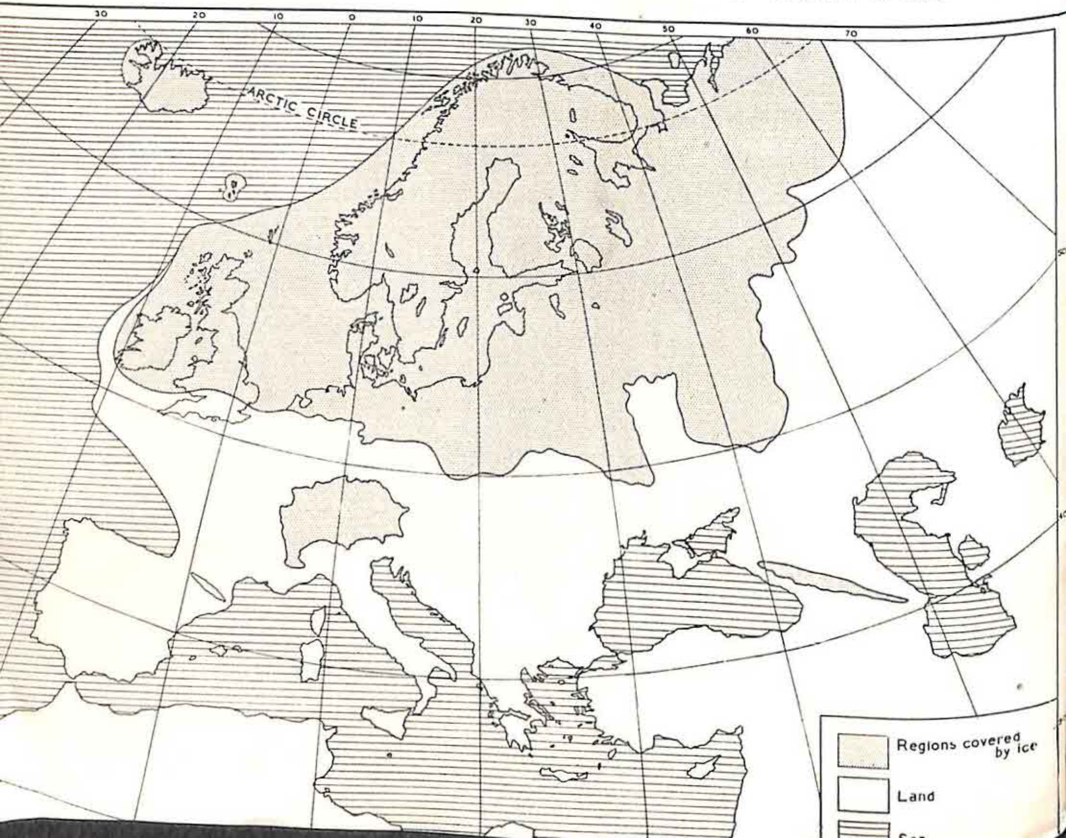
Question 5. **What Changes of Climate have there been on the Earth?**

The ancient coal deposits were formed in warm swamps. We know this because the plant fossils which are found in coal come from things that can live only in warm places. But today we find coal not only in warm and temperate lands, but also in Alaska, Greenland, Spitzbergen, and even in the frozen wastes of Antarctica. Thus the climate of these cold regions must at one time have been more or less like that of Malaya or the Amazon forests today.

We know, too, that hundreds of millions of years ago some parts of the world, which today have warm or hot climates, were as cold as Greenland is today.

FIGURE 63. The Ice Age in Europe.

(Modified from Sollas, *Ancient Hunters*, Macmillan & Co. Ltd.)



At that time they must have been covered with a tremendous sheet of ice. We know this because we can find in these regions rocks that have been scratched and polished by the action of moving ice. We can also find these deposits of rocks, sand and gravel that have been brought to their present position by ice. Remains of this early Ice Age of long, long ago are found in India, in Africa south of the Equator and in southern Australia.

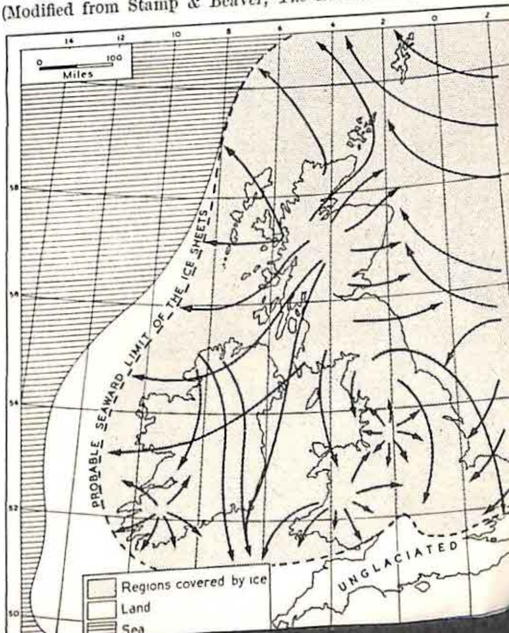
The Great Ice Age. But there was another Ice Age of comparatively recent time, the one which has so profoundly affected northern Europe and North America. About a million years ago the climate of the whole earth was cooler than it is today. The average temperature may not have been more than ten degrees lower, but the skies in summer were much more covered with clouds and so the summer sun had less chance of melting the winter snows.

The map in Figure 63 shows you how far the ice-sheet once extended in Europe and how the ice of Switzerland had extended northwards into what is now Germany and France.

The map in Figure 64 shows the extent of glaciers in the British Isles. Several glacial centres are shown and the direction of the movement of the ice is indicated by the arrows. These lines have been found by matching the stones left behind by glaciers with the mountain rocks from which they must have been fetched.

FIGURE 64. The Ice Age in Britain. The arrows show directions in which ice moved.

(Modified from Stamp & Beaver, *The British Isles*)



We know that the Scandinavian ice-sheet, or icebergs from that sheet, must have reached Britain, for on the east coast we find enormous blocks of igneous rocks that can only be matched around the fjords of Norway.

Ice-sheets moved, and still move, much as valley glaciers do. Even so you may wonder how they could cover so much country. The answer is that the sheets grew and spread out for thousands of years.

One of the fascinating parts of the story is that there were many changes during the length of the Great Ice Age. After the first spread of the glaciers there came a time of warmth and melting. Climates were mild again, even warmer than today. Wild animals roamed through forests where ice had been. Beds of peat filled the swamps. But the cold returned again and again. Ice buried the forests and killed the beasts or drove them southward. Not only once, but four times at least the great ice-sheets formed and melted again. The last one must have retreated from northern Europe relatively recently. Indeed, it is only about eight thousand years since the ice left southern Sweden, and this is a very short time in terms of earth history. It is possible that the present period is merely another mild period of the Great Ice Age and that the ice-sheets will return again a few thousand years hence!

The foregoing are only a few of the many changes which have taken place, and are still taking place, on this earth of ours. What signs of changes can you see with your own eyes?

SOME THINGS YOU MAY CARE TO DO

1. Do you know a swamp where the plant material has collected to form *peat* ? This is the first stage in the formation of coal. If you find some, examine it to see if you can learn what kinds of plants it contains.

2. Do you know a place where there is a seam of coal ? If you can visit such a place, find out what kinds of rock are near the coal.

3. Do you live in a region once covered by an ice-sheet ? If so, you ought to find many signs of its former existence.

FIGURE 65. A scientist's reconstruction of a Coal Measure forest. Note the giant horsetail tree in the foreground. Horsetail trees still exist today but grow to a height of only a few feet.

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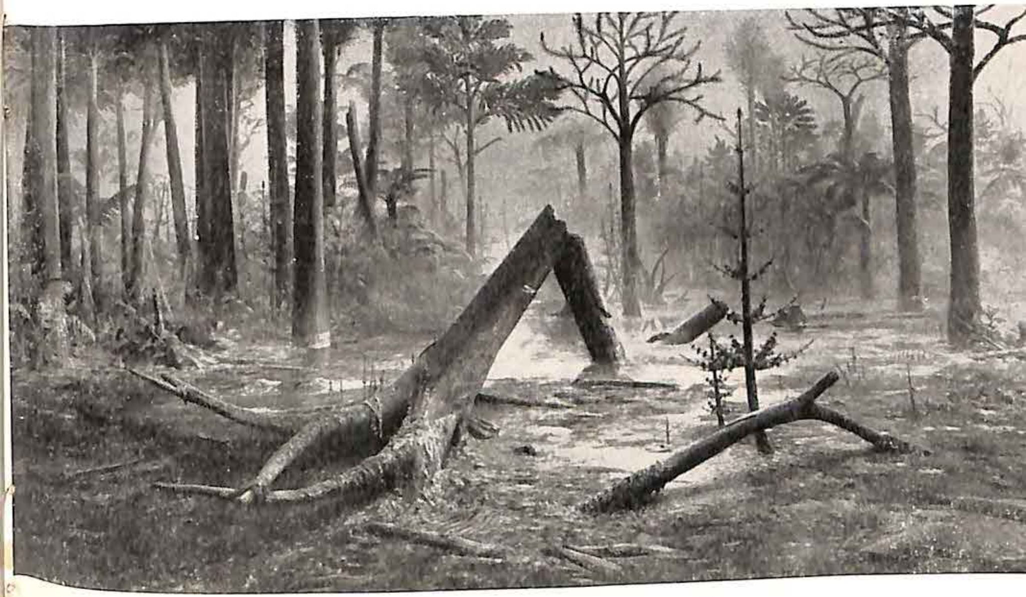

REVIEW QUESTIONS ON THE WEATHER

1. What do we mean when we say "weather"?
2. How do we measure temperature changes?
3. What is the freezing point of water on the Fahrenheit scale? On the Centigrade scale?
4. What is the boiling point of water on the Fahrenheit scale? On the Centigrade scale?
5. What is wind?
6. Does the wind blow towards a region of high pressure or away from it?
7. Is moist air heavier or lighter than dry air?
8. With what instrument do we measure air pressure?
9. In what direction is a north wind blowing?
10. What is meant by a "wet wind"?
11. What is meant by "condensation" of water?
12. What is a cloud?
13. Why is the Meteorological Office a branch of the Air Ministry in Great Britain?
14. What are the sources of the water vapour in the air?
15. Mention six forms in which water may condense, and explain briefly how they differ.

TEST—A MATCHING EXERCISE

Each of the terms in the second column has a close connection with one of the terms in the first column. Copy the first column on paper, and write beside each term the one from the second column that belongs with it.

1. Glaciers
2. Sedimentary rock
3. Lava
4. Coal
5. Rivers
6. Fossils
7. States of matter
8. Sand dunes
9. Erosion
10. Igneous rock

Sandstone
Molten rock
Tropical swamp
Granite
Petrified trees
Ice Age
Running water
Alluvial plain
Solid, liquid, and gas
Wind action

REVIEW QUESTIONS ON THE EARTH

1. Are all the materials that make up the earth solid? If not, what are they?

2. How does heat change the materials of the earth?

3. What are two causes of changes in rocks below the earth's surface?

4. What do scientists mean by the word "rock"?

5. How do igneous rocks differ from sedimentary rocks?

6. Can you find near your home any kinds of rock formed by volcanic action?

7. How has the depositing of sediments changed the earth in your home region?

8. Account for the formation of coal.

9. How can we read in rocks the stories of strange plants and animals of former times?

10. Account for the formation of fossils.

11. Account for the formation of petrified wood.

12. What two groups of forces are continually working on the earth's surface, one building it up, the other tearing it down?

13. How does the weather affect rocks?

14. Why are stucco houses not very satisfactory in regions where the winters are very cold?

15. How do you explain the fact that mountain streams are usually clear and lowland streams muddy?

16. Do stones that are exposed to the air increase or decrease in size?

17. How is a glacier formed?

18. How does ice-borne earth material differ from water-borne material?

19. What is the story of the Great Ice Age?

20. What ways are there of distinguishing igneous from sedimentary rocks?

A TEST ON THE SCIENTIFIC METHOD

Two things that are true about a scientist are:

1. He observes carefully and uses his observations to form conclusions.

2. He is open-minded. He reaches a conclusion only when he thinks he has satisfactory evidence.

Some boys who had been reading about the earth and its rocks went on a hike one Saturday. They found a big rock which looked interesting, and started the following conversation. You are to tell whether or not each sentence showed the scientific method of thinking, as stated in the two rules given above.

Fred. "See that rock that glistens in the sun? It must be shale."

Paul. "Why do you think it is shale? It seems to have a lot of different colours in it."

Fred. "Well, shale is hardened mud, and mud has all kinds of things in it."

Tom. "I can see bits of shiny stuff that look like broken mirrors. I have seen bits like that on the beach. It is sandstone."

Paul. "It doesn't look like hardened sand to me. Some of the particles are much bigger than others, and sand particles are all about the same size. I think it is granite."

Harry. "Does it have crystals in it? I think I can see some that look almost like glass. Perhaps it is obsidian."

Paul. "I can see crystals, but granite has crystals too, you know."

Tom. "But it is a kind of pink colour. I still vote for sandstone. You know a lot of sandstone is pink."

Paul. "But pink sandstone might be made of bits of broken pink granite. Don't you agree that it is granite?"

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